TIM
MAUDLIN
WHO
IS THE
QUANTUM
OBSERVER?

1
00:00:04,789 --> 00:00:02,990
Tim Maudlin is a professor at NYU a

2
00:00:06,410 --> 00:00:04,799
visiting professor at Harvard and

3
00:00:07,970 --> 00:00:06,420
Carnegie Mellon as well as an

4
00:00:09,650 --> 00:00:07,980
influential philosopher of science

5
00:00:12,169 --> 00:00:09,660
specializing in the metaphysical

6
00:00:14,030 --> 00:00:12,179
foundations of physics and logic today

7
00:00:15,890 --> 00:00:14,040
we discuss various interpretations of

8
00:00:17,689 --> 00:00:15,900
quantum mechanics including Bohemian

9
00:00:19,189 --> 00:00:17,699
mechanics which is also known as pilot

10
00:00:20,929 --> 00:00:19,199
wave theory we talk about super

11
00:00:22,490 --> 00:00:20,939
determinism as well as how quantum

12
00:00:25,070 --> 00:00:22,500
mechanics can be formulated without

13
00:00:27,109 --> 00:00:25,080

observers also reformulations are the

14
00:00:29,630 --> 00:00:27,119
foundations of physics without numbers

15
00:00:31,849 --> 00:00:29,640
and also how to place time as Primal

16
00:00:33,650 --> 00:00:31,859
rather than a derived notion or rather

17
00:00:35,810 --> 00:00:33,660
than spatializing time which is what's

18
00:00:37,910 --> 00:00:35,820
generally done next time with Tim we'll

19
00:00:39,830 --> 00:00:37,920
also get to the Liars Paradox and

20
00:00:41,510 --> 00:00:39,840
computation and Consciousness write down

21
00:00:43,190 --> 00:00:41,520
your questions below because Tim will

22
00:00:45,590 --> 00:00:43,200
most likely be coming on again for a

23
00:00:46,970 --> 00:00:45,600
part two today's sponsor is brilliant if

24
00:00:48,650 --> 00:00:46,980
you're familiar with toe you're familiar

25
00:00:50,630 --> 00:00:48,660
with Brilliance but for those who don't

26
00:00:52,670 --> 00:00:50,640
know Brilliance is a place where you go

27
00:00:54,590 --> 00:00:52,680
to learn math science and engineering

28
00:00:56,689 --> 00:00:54,600
through these bite-sized Interactive

29
00:00:58,310 --> 00:00:56,699
Learning experiences for example and I

30
00:00:59,990 --> 00:00:58,320
keep saying this I would like to do a

31
00:01:02,510 --> 00:01:00,000
podcast on information Theory

32
00:01:04,850 --> 00:01:02,520
particularly Chiara marleto which is

33
00:01:06,410 --> 00:01:04,860
David Deutsch's student has a theory of

34
00:01:08,330 --> 00:01:06,420
everything that she puts forward called

35
00:01:10,429 --> 00:01:08,340
Constructor Theory which is heavily

36
00:01:12,170 --> 00:01:10,439
contingent on information Theory so I

37
00:01:13,850 --> 00:01:12,180
took their course on random variable

38
00:01:15,950 --> 00:01:13,860

distributions and knowledge and

39
00:01:17,929 --> 00:01:15,960
uncertainty in order to learn a bit more

40
00:01:19,730 --> 00:01:17,939
about entropy now there's this formula

41
00:01:21,710 --> 00:01:19,740
for entropy essentially hammered into

42
00:01:23,630 --> 00:01:21,720
you as an undergraduate which seems to

43
00:01:25,429 --> 00:01:23,640
have fallen from the sky however when

44
00:01:26,929 --> 00:01:25,439
you take Brilliance course it was the

45
00:01:29,690 --> 00:01:26,939
first time that I could see that it's an

46
00:01:31,969 --> 00:01:29,700
extremely clear and intuitive formula

47
00:01:33,649 --> 00:01:31,979
that is to say that it would be

48
00:01:36,710 --> 00:01:33,659
unnatural to Define it in any other

49
00:01:38,870 --> 00:01:36,720
manner visit brilliant.org toe that is

50
00:01:40,730 --> 00:01:38,880
t-o-e to get 20 off the annual

51
00:01:43,310 --> 00:01:40,740
subscription and I recommend that you

52
00:01:45,050 --> 00:01:43,320
don't stop before four lessons I think

53
00:01:46,609 --> 00:01:45,060
you'll be greatly surprised that the

54
00:01:48,770 --> 00:01:46,619
ease at which you can now comprehend

55
00:01:50,749 --> 00:01:48,780
subjects you previously had a difficult

56
00:01:51,950 --> 00:01:50,759
time grocking at some point I'll also go

57
00:01:54,289 --> 00:01:51,960
through the courses and give a

58
00:01:56,510 --> 00:01:54,299
recommendation in order thank you and

59
00:01:58,789 --> 00:01:56,520
enjoy Professor I should let you know

60
00:01:59,749 --> 00:01:58,799
that I'm extremely extremely excited to

61
00:02:01,730 --> 00:01:59,759
speak with you you're one of the

62
00:02:02,990 --> 00:02:01,740
brightest minds and most clear minds and

63
00:02:04,550 --> 00:02:03,000

those don't go hand in hand usually

64
00:02:06,350 --> 00:02:04,560
someone else that has those two

65
00:02:07,730 --> 00:02:06,360
qualities is John bias Who's down to

66
00:02:10,370 --> 00:02:07,740
Earth but extremely bright at the same

67
00:02:12,710 --> 00:02:10,380
time reading his stuff yeah usually when

68
00:02:15,530 --> 00:02:12,720
I interview someone they have one or two

69
00:02:16,430 --> 00:02:15,540
distinctive ideas whereas for you I feel

70
00:02:18,410 --> 00:02:16,440
like

71
00:02:19,309 --> 00:02:18,420
I flip through your papers and there's

72
00:02:21,410 --> 00:02:19,319
such a

73
00:02:22,670 --> 00:02:21,420
a multitude it's like Douglas hofstetter

74
00:02:23,809 --> 00:02:22,680
I'm gonna have to use this as an

75
00:02:25,910 --> 00:02:23,819
introductory and hopefully you'll come

76
00:02:27,050 --> 00:02:25,920
back on to speak about all of them what

77
00:02:28,490 --> 00:02:27,060
is it about your work that's most

78
00:02:30,770 --> 00:02:28,500
exciting parenthetically you can talk

79
00:02:31,670 --> 00:02:30,780
about what that work is

80
00:02:33,490 --> 00:02:31,680
um

81
00:02:36,410 --> 00:02:33,500
well

82
00:02:39,830 --> 00:02:36,420
I I because I'm in a philosophy

83
00:02:42,350 --> 00:02:39,840
Department I have this uh amazing

84
00:02:45,050 --> 00:02:42,360
freedom to pretty much look into

85
00:02:47,710 --> 00:02:45,060
whatever I feel like looking into which

86
00:02:52,070 --> 00:02:47,720
is why if you look through my work it's

87
00:02:52,869 --> 00:02:52,080
covers a variety of different fields

88
00:02:55,369 --> 00:02:52,879

um

89
00:02:57,110 --> 00:02:55,379
most of my work has been in foundations

90
00:03:00,050 --> 00:02:57,120
of physics although I have some other

91
00:03:03,410 --> 00:03:00,060
stuff in semantics uh paper on

92
00:03:06,229 --> 00:03:03,420
Consciousness and various other

93
00:03:07,250 --> 00:03:06,239
philosophy of science topics

94
00:03:10,610 --> 00:03:07,260
um

95
00:03:13,070 --> 00:03:10,620
at the moment what's most exciting is is

96
00:03:17,630 --> 00:03:13,080
some work I've been doing

97
00:03:19,430 --> 00:03:17,640
for the last gosh five years

98
00:03:21,350 --> 00:03:19,440
um which has gone in a direction I never

99
00:03:24,130 --> 00:03:21,360
really anticipated

100
00:03:26,390 --> 00:03:24,140
uh which is working on discrete geometry

101
00:03:29,270 --> 00:03:26,400
and ways to

102
00:03:31,190 --> 00:03:29,280
understand space and time as as having a

103
00:03:33,410 --> 00:03:31,200
discrete rather The Continuous structure

104
00:03:36,470 --> 00:03:33,420
and um

105
00:03:39,710 --> 00:03:36,480
just within the last

106
00:03:41,570 --> 00:03:39,720
six months or so I got to the point of

107
00:03:44,630 --> 00:03:41,580
actually

108
00:03:46,970 --> 00:03:44,640
having a structure

109
00:03:49,729 --> 00:03:46,980
and doing some calculations and suddenly

110
00:03:51,410 --> 00:03:49,739
finding uh relativity kind of falling

111
00:03:53,470 --> 00:03:51,420
out into my lap from foundations

112
00:03:55,430 --> 00:03:53,480
literature about as

113
00:03:57,770 --> 00:03:55,440

unrelativistic as you could possibly

114
00:03:59,990 --> 00:03:57,780
imagine so that's to me has been very

115
00:04:01,430 --> 00:04:00,000
exciting whether it will go anywhere at

116
00:04:02,930 --> 00:04:01,440
the end of the day or not I don't know

117
00:04:04,910 --> 00:04:02,940
but it um

118
00:04:06,789 --> 00:04:04,920
if nothing else it's an illustration

119
00:04:10,729 --> 00:04:06,799
that's

120
00:04:13,009 --> 00:04:10,739
relativistic structure May emerge in a

121
00:04:15,589 --> 00:04:13,019
very natural way from a foundation that

122
00:04:17,990 --> 00:04:15,599
looks completely unrelativistic so that

123
00:04:19,909 --> 00:04:18,000
to me has been quite exciting

124
00:04:21,110 --> 00:04:19,919
um so that's what I've been doing most

125
00:04:23,749 --> 00:04:21,120
recently I mean there's some other

126
00:04:25,909 --> 00:04:23,759
things trying to get trying to get

127
00:04:27,710 --> 00:04:25,919
numbers out of physics I I don't like

128
00:04:29,030 --> 00:04:27,720
having numbers in physics so I've been

129
00:04:30,590 --> 00:04:29,040
trying to get rid of them and I made

130
00:04:31,430 --> 00:04:30,600
some progress on that

131
00:04:34,070 --> 00:04:31,440
um

132
00:04:36,310 --> 00:04:34,080
a variety thank you okay you're gonna

133
00:04:39,950 --> 00:04:36,320
have to elaborate on that last Point

134
00:04:41,270 --> 00:04:39,960
well okay so I can say some things very

135
00:04:42,530 --> 00:04:41,280
simply

136
00:04:44,629 --> 00:04:42,540
um

137
00:04:47,210 --> 00:04:44,639
if you go back to ancient Greece which

138
00:04:50,450 --> 00:04:47,220

is always a nice place to go back to and

139
00:04:53,390 --> 00:04:50,460
ancient Greeks mathematics was divided

140
00:04:55,610 --> 00:04:53,400
into two sub-disciplines

141
00:04:57,170 --> 00:04:55,620
arithmetic and geometry and arithmetic

142
00:04:59,570 --> 00:04:57,180
was a theory of numbers and of course

143
00:05:02,450 --> 00:04:59,580
through the Greeks the numbers

144
00:05:04,070 --> 00:05:02,460
are well what we would normally say what

145
00:05:07,189 --> 00:05:04,080
we would call the counting numbers right

146
00:05:09,350 --> 00:05:07,199
the positive integers although in a way

147
00:05:11,390 --> 00:05:09,360
the numbers for the Greeks started with

148
00:05:14,210 --> 00:05:11,400
two not with one

149
00:05:17,330 --> 00:05:14,220
which is as I like to point out also the

150
00:05:20,270 --> 00:05:17,340
way we talk right you know why

151
00:05:22,550 --> 00:05:20,280
um because if if someone says if if

152
00:05:24,170 --> 00:05:22,560
someone says do you do you have any pets

153
00:05:27,050 --> 00:05:24,180
and I say yes I have a number of pets

154
00:05:28,850 --> 00:05:27,060
the number is one yeah that's like a

155
00:05:31,189 --> 00:05:28,860
joke right if I say I have a number of

156
00:05:32,810 --> 00:05:31,199
pets you think I have at least two

157
00:05:34,490 --> 00:05:32,820
um yeah I say I have a number of pets

158
00:05:36,770 --> 00:05:34,500
and the number is zero then it's really

159
00:05:38,270 --> 00:05:36,780
a bad joke right then you say you know

160
00:05:39,409 --> 00:05:38,280
that just doesn't count as a number of

161
00:05:41,810 --> 00:05:39,419
anything

162
00:05:44,210 --> 00:05:41,820
um and and interesting we can't count

163
00:05:47,029 --> 00:05:44,220

one is a number of things

164
00:05:48,890 --> 00:05:47,039
um so you know if you just follow that

165
00:05:50,029 --> 00:05:48,900
language you'd say yeah when you're when

166
00:05:51,529 --> 00:05:50,039
you're talking about the numbers you're

167
00:05:55,010 --> 00:05:51,539
talking about beginning with two that's

168
00:05:58,550 --> 00:05:55,020
why one was very special for the Greeks

169
00:06:01,790 --> 00:05:58,560
um one we all have a number of phds yeah

170
00:06:03,350 --> 00:06:01,800
yeah exactly you know so it's not so

171
00:06:05,749 --> 00:06:03,360
strange anyway so there was number

172
00:06:07,850 --> 00:06:05,759
Theory and then there was there was

173
00:06:10,310 --> 00:06:07,860
geometry which was the theory of of

174
00:06:13,430 --> 00:06:10,320
continuous magnitudes of space basically

175
00:06:16,189 --> 00:06:13,440
I mean and and between the two of them

176
00:06:19,430 --> 00:06:16,199
the balance was very much on the side of

177
00:06:23,749 --> 00:06:19,440
geometry I mean you had all of Euclid 13

178
00:06:26,510 --> 00:06:23,759
books of Euclid with amazing proofs okay

179
00:06:28,730 --> 00:06:26,520
you know proofs of of things you would

180
00:06:30,650 --> 00:06:28,740
never imagine would even be true much

181
00:06:33,230 --> 00:06:30,660
less provable

182
00:06:34,790 --> 00:06:33,240
um and Euclid everybody knows Euclid not

183
00:06:36,950 --> 00:06:34,800
that many people have heard of nicomicus

184
00:06:39,290 --> 00:06:36,960
of Rhodes who was sort of the the top

185
00:06:42,230 --> 00:06:39,300
guy in arithmetic

186
00:06:44,270 --> 00:06:42,240
um and and that was the balance for uh

187
00:06:45,469 --> 00:06:44,280
for a couple Millennia was that if you

188
00:06:49,309 --> 00:06:45,479

look at math

189
00:06:53,029 --> 00:06:49,319
it was it was the queen of of math was

190
00:06:56,150 --> 00:06:53,039
geometry and number theory was kind of

191
00:06:58,490 --> 00:06:56,160
um lower down and if you look at Newton

192
00:07:00,290 --> 00:06:58,500
and Galileo and so on all of their

193
00:07:02,570 --> 00:07:00,300
proofs are basically used the tools of

194
00:07:03,950 --> 00:07:02,580
geometry

195
00:07:07,249 --> 00:07:03,960
um

196
00:07:09,290 --> 00:07:07,259
and what you notice is that is it if I

197
00:07:11,270 --> 00:07:09,300
tell you the physical world has a

198
00:07:13,309 --> 00:07:11,280
geometrical structure

199
00:07:16,430 --> 00:07:13,319
that seems like a very natural thing to

200
00:07:18,290 --> 00:07:16,440
say I mean geometry is a was thought to

201
00:07:20,150 --> 00:07:18,300
be about the structure of space itself

202
00:07:22,010 --> 00:07:20,160
and space itself is part of the physical

203
00:07:22,730 --> 00:07:22,020
world

204
00:07:28,430 --> 00:07:22,740
um

205
00:07:30,770 --> 00:07:28,440
structure it's not quite immediately so

206
00:07:33,170 --> 00:07:30,780
clear what I could mean I mean people

207
00:07:35,029 --> 00:07:33,180
it's reported that the pythagoreans who

208
00:07:37,010 --> 00:07:35,039
love numbers said things like a horse is

209
00:07:39,170 --> 00:07:37,020
the number 10 and you just go like what

210
00:07:42,110 --> 00:07:39,180
in the world are you talking about

211
00:07:44,990 --> 00:07:42,120
um you know how can a horse you know how

212
00:07:46,430 --> 00:07:45,000
can a course be the number ten uh the

213
00:07:49,850 --> 00:07:46,440

the connection

214
00:07:53,529 --> 00:07:49,860
um between numbers I I think

215
00:07:55,790 --> 00:07:53,539
it's a very good therapy

216
00:07:57,710 --> 00:07:55,800
whenever you're looking at mathematical

217
00:08:00,409 --> 00:07:57,720
physics and you've got algebraic

218
00:08:02,450 --> 00:08:00,419
structure numerical structure to ask

219
00:08:05,870 --> 00:08:02,460
yourself where it came from

220
00:08:08,270 --> 00:08:05,880
because usually it's introduced by means

221
00:08:10,730 --> 00:08:08,280
of some convention like by means of say

222
00:08:13,249 --> 00:08:10,740
putting down a coordinate system and

223
00:08:17,270 --> 00:08:13,259
assigning numbers as coordinates

224
00:08:18,529 --> 00:08:17,280
and because that's not intrinsic to the

225
00:08:21,350 --> 00:08:18,539
subject

226
00:08:22,730 --> 00:08:21,360
they're an infinite number of ways to do

227
00:08:24,850 --> 00:08:22,740
that and then you have to be very

228
00:08:27,710 --> 00:08:24,860
careful about

229
00:08:30,950 --> 00:08:27,720
what in your representation is a mere

230
00:08:32,810 --> 00:08:30,960
artifact of the of the conventions and

231
00:08:34,430 --> 00:08:32,820
what corresponds to something that's

232
00:08:35,990 --> 00:08:34,440
really there

233
00:08:37,969 --> 00:08:36,000
um this is the kind of thing Einstein

234
00:08:39,649 --> 00:08:37,979
says I mean the the reason it took him

235
00:08:41,750 --> 00:08:39,659
10 years to get from special relativity

236
00:08:44,389 --> 00:08:41,760
to general relativity and he says this I

237
00:08:45,530 --> 00:08:44,399
think in the autobiography in the in the

238
00:08:48,670 --> 00:08:45,540

show volume

239
00:08:50,990 --> 00:08:48,680
is that he kept thinking that the

240
00:08:53,290 --> 00:08:51,000
coordinates had to have some physical

241
00:08:56,509 --> 00:08:53,300
significance

242
00:08:58,790 --> 00:08:56,519
and and it took him a long time to

243
00:09:00,850 --> 00:08:58,800
understand that they don't and in order

244
00:09:04,190 --> 00:09:00,860
to have a mathematical

245
00:09:06,230 --> 00:09:04,200
structure that's capable of handling

246
00:09:08,870 --> 00:09:06,240
curved space time

247
00:09:11,810 --> 00:09:08,880
it has to be there are no special

248
00:09:14,090 --> 00:09:11,820
coordinate systems right in a flat space

249
00:09:15,650 --> 00:09:14,100
Cartesian coordinates are special and in

250
00:09:17,389 --> 00:09:15,660
a flat space time where rents

251
00:09:19,610 --> 00:09:17,399
coordinates are special

252
00:09:21,769 --> 00:09:19,620
and you tend to only use them and

253
00:09:23,870 --> 00:09:21,779
they're very convenient in a curve space

254
00:09:26,329 --> 00:09:23,880
in a variably curved space there are no

255
00:09:27,829 --> 00:09:26,339
special coordinate systems and you

256
00:09:29,570 --> 00:09:27,839
you're really confronted with the fact

257
00:09:32,329 --> 00:09:29,580
that the coordinate values don't mean

258
00:09:34,430 --> 00:09:32,339
anything by themselves and then you have

259
00:09:36,769 --> 00:09:34,440
to think hard about what does mean

260
00:09:39,290 --> 00:09:36,779
something right what are the quantities

261
00:09:40,910 --> 00:09:39,300
that really characterize the space

262
00:09:44,509 --> 00:09:40,920
itself

263
00:09:46,130 --> 00:09:44,519

um so you know it there's an interesting

264
00:09:49,670 --> 00:09:46,140
history here it starts actually with

265
00:09:51,949 --> 00:09:49,680
Descartes among people in in La geometry

266
00:09:53,870 --> 00:09:51,959
where he introduces not what we would

267
00:09:55,670 --> 00:09:53,880
call Cartesian coordinates but he's very

268
00:09:57,650 --> 00:09:55,680
clear because

269
00:09:59,990 --> 00:09:57,660
and I'm sorry to be going on so long but

270
00:10:02,930 --> 00:10:00,000
you still no it's fine please

271
00:10:06,370 --> 00:10:02,940
um you know it was known from the Middle

272
00:10:09,829 --> 00:10:06,380
Ages and especially the Arabic Scholars

273
00:10:13,370 --> 00:10:09,839
that if you're doing number Theory

274
00:10:15,290 --> 00:10:13,380
then you can do use algebraic methods to

275
00:10:17,530 --> 00:10:15,300
solve problems and that the algebraic

276
00:10:21,710 --> 00:10:17,540
methods were really powerful

277
00:10:24,230 --> 00:10:21,720
and so what Descartes asked himself is

278
00:10:27,769 --> 00:10:24,240
huh I wonder if there's a way that I can

279
00:10:29,269 --> 00:10:27,779
somehow use algebra to solve geometry

280
00:10:32,870 --> 00:10:29,279
problems

281
00:10:35,210 --> 00:10:32,880
and what he was interested in was was

282
00:10:38,150 --> 00:10:35,220
doing that he's very clear about what

283
00:10:41,449 --> 00:10:38,160
he's doing and in fact one of the things

284
00:10:43,730 --> 00:10:41,459
he realizes is that in numbers when

285
00:10:45,710 --> 00:10:43,740
you're dealing with numbers one is a

286
00:10:48,290 --> 00:10:45,720
special number right it's the only

287
00:10:49,430 --> 00:10:48,300
number that squares to itself besides

288
00:10:50,810 --> 00:10:49,440

zero

289
00:10:52,670 --> 00:10:50,820
um it's the only number that when you

290
00:10:55,250 --> 00:10:52,680
multiply it by anything else you get the

291
00:10:56,569 --> 00:10:55,260
same thing back so one is just picked

292
00:10:59,210 --> 00:10:56,579
out

293
00:11:01,310 --> 00:10:59,220
from the algebraic structure as really

294
00:11:03,290 --> 00:11:01,320
special but when you're doing geometry

295
00:11:05,630 --> 00:11:03,300
there's no unit that's special there's

296
00:11:08,630 --> 00:11:05,640
no length that's special so Descartes

297
00:11:11,269 --> 00:11:08,640
realized that in order to convert

298
00:11:15,650 --> 00:11:11,279
geometrical problems into algebraic ones

299
00:11:21,769 --> 00:11:18,350
um which is really important

300
00:11:24,410 --> 00:11:21,779
and is this overcome with a fine spaces

301
00:11:27,590 --> 00:11:24,420
rather than just a vector space well it

302
00:11:29,690 --> 00:11:27,600
it was look he's doing in a Continuum I

303
00:11:31,069 --> 00:11:29,700
mean his interest in Geometry or in a

304
00:11:33,710 --> 00:11:31,079
continuum

305
00:11:36,050 --> 00:11:33,720
and no link is special on a Continuum I

306
00:11:38,030 --> 00:11:36,060
mean you've got all these lines the the

307
00:11:40,790 --> 00:11:38,040
other thing that's that's that is worth

308
00:11:42,530 --> 00:11:40,800
noting is that if you're dealing with

309
00:11:44,569 --> 00:11:42,540
numbers what part of what makes

310
00:11:47,329 --> 00:11:44,579
something a number field why we even

311
00:11:49,490 --> 00:11:47,339
call a set of objects numbers at all is

312
00:11:50,870 --> 00:11:49,500
that you can multiply them and when I

313
00:11:52,490 --> 00:11:50,880

multiply two numbers I get another

314
00:11:55,370 --> 00:11:52,500
number

315
00:11:57,590 --> 00:11:55,380
but there's no there's no corresponding

316
00:11:59,930 --> 00:11:57,600
geometrical operation

317
00:12:03,050 --> 00:11:59,940
if I give you two magnitudes if I give

318
00:12:05,389 --> 00:12:03,060
you two line segments say

319
00:12:07,310 --> 00:12:05,399
there's no operation corresponding to

320
00:12:09,710 --> 00:12:07,320
multiplication that will hand me back

321
00:12:12,350 --> 00:12:09,720
another line segment the best you can do

322
00:12:15,889 --> 00:12:12,360
in a euclidean space you can make an

323
00:12:18,290 --> 00:12:15,899
area right you can make a rectangle

324
00:12:20,630 --> 00:12:18,300
um but the rectangle is a different kind

325
00:12:22,370 --> 00:12:20,640
of thing I mean the the units in which

326
00:12:26,630 --> 00:12:22,380
you characterize it are different than

327
00:12:28,370 --> 00:12:26,640
than the lengths so there's no natural

328
00:12:31,190 --> 00:12:28,380
object that corresponds to

329
00:12:33,410 --> 00:12:31,200
multiplication in geometry

330
00:12:35,389 --> 00:12:33,420
but we use multiplication all the time

331
00:12:36,590 --> 00:12:35,399
in doing physics because we've converted

332
00:12:38,870 --> 00:12:36,600
everything into numerical

333
00:12:40,790 --> 00:12:38,880
representations right just to be clear

334
00:12:42,710 --> 00:12:40,800
let me just see if I'm breaking it down

335
00:12:45,050 --> 00:12:42,720
correctly if you don't mind so when you

336
00:12:47,269 --> 00:12:45,060
say hey if we have two lengths or two

337
00:12:49,970 --> 00:12:47,279
line segments it's not obvious how to

338
00:12:52,129 --> 00:12:49,980

multiply them right so someone may say

339
00:12:53,629 --> 00:12:52,139
well can you add them you can add the

340
00:12:54,550 --> 00:12:53,639
lengths okay you can add the lengths

341
00:12:56,810 --> 00:12:54,560
yeah

342
00:12:59,090 --> 00:12:56,820
and then they may think well no I can

343
00:13:00,829 --> 00:12:59,100
multiply well you think you have some

344
00:13:02,030 --> 00:13:00,839
way of multiplying let me tell you this

345
00:13:03,650 --> 00:13:02,040
first line segment was actually the

346
00:13:05,509 --> 00:13:03,660
number one so your way of multiplying

347
00:13:08,269 --> 00:13:05,519
actually doesn't change it so you think

348
00:13:09,650 --> 00:13:08,279
hey I did some complex and then I could

349
00:13:11,269 --> 00:13:09,660
just say no this first line was number

350
00:13:12,650 --> 00:13:11,279
two so that's why you say that there

351
00:13:13,790 --> 00:13:12,660
needs to be a unit picked out in order

352
00:13:15,769 --> 00:13:13,800
to multiply when you're thinking about

353
00:13:17,990 --> 00:13:15,779
line segments well it's not it's not

354
00:13:19,730 --> 00:13:18,000
just which comes first I mean certainly

355
00:13:21,530 --> 00:13:19,740
multiplication should be an operation

356
00:13:24,590 --> 00:13:21,540
that commutes it shouldn't matter what

357
00:13:26,569 --> 00:13:24,600
order I I give them to you the real

358
00:13:28,910 --> 00:13:26,579
problem is

359
00:13:31,670 --> 00:13:28,920
um the number one is the multiplicative

360
00:13:34,250 --> 00:13:31,680
unit so when I multiply

361
00:13:36,230 --> 00:13:34,260
any other number by one I get the same

362
00:13:40,370 --> 00:13:36,240
number back again

363
00:13:44,329 --> 00:13:40,380

and and there's no geometrical length

364
00:13:49,910 --> 00:13:46,670
um that's why that's why Descartes says

365
00:13:52,250 --> 00:13:49,920
in order to convert a geometrical

366
00:13:56,090 --> 00:13:52,260
problem into an algebraic one I have to

367
00:13:58,009 --> 00:13:56,100
make an arbitrary choice of unit I'm

368
00:13:59,170 --> 00:13:58,019
going to say oh this length counts as

369
00:14:02,090 --> 00:13:59,180
one

370
00:14:04,250 --> 00:14:02,100
if I do that then I can define something

371
00:14:06,290 --> 00:14:04,260
that you would call multiplication right

372
00:14:07,790 --> 00:14:06,300
not now suppose I have this special

373
00:14:10,370 --> 00:14:07,800
length that I've just picked out of the

374
00:14:13,129 --> 00:14:10,380
air I oh that's length one

375
00:14:15,410 --> 00:14:13,139
now I give you two other links A and B

376
00:14:16,490 --> 00:14:15,420
and then you make a rectangle out of a

377
00:14:19,009 --> 00:14:16,500
and b

378
00:14:21,170 --> 00:14:19,019
which has an area and now you say well

379
00:14:24,050 --> 00:14:21,180
if I want another rectangle with the

380
00:14:25,190 --> 00:14:24,060
same area but one of the sides is the

381
00:14:30,350 --> 00:14:25,200
unit

382
00:14:33,829 --> 00:14:30,360
other side have to be

383
00:14:35,870 --> 00:14:33,839
and then that will give me a length

384
00:14:37,250 --> 00:14:35,880
but it's only relative to the choice of

385
00:14:39,590 --> 00:14:37,260
that unit if I choose choose a different

386
00:14:42,650 --> 00:14:39,600
unit I'll get a different one so how are

387
00:14:44,569 --> 00:14:42,660
you going to create all of this richness

388
00:14:46,490 --> 00:14:44,579

of standard multiplication and addition

389
00:14:49,430 --> 00:14:46,500
using geometry

390
00:14:51,110 --> 00:14:49,440
um you you don't you don't try to to

391
00:14:53,629 --> 00:14:51,120
replicate

392
00:14:56,569 --> 00:14:53,639
the thing about multiplication

393
00:14:58,310 --> 00:14:56,579
is that again it's a function that takes

394
00:15:00,710 --> 00:14:58,320
two numbers as input and gives you a

395
00:15:03,230 --> 00:15:00,720
number back as output so I can just

396
00:15:05,030 --> 00:15:03,240
iterate and multiply and re-multiply and

397
00:15:07,370 --> 00:15:05,040
Cube and so on

398
00:15:10,069 --> 00:15:07,380
um the the proper

399
00:15:11,210 --> 00:15:10,079
operation in Geometry if I give you two

400
00:15:13,550 --> 00:15:11,220
lengths

401
00:15:15,110 --> 00:15:13,560
is it I can construct something out of

402
00:15:17,509 --> 00:15:15,120
it but what I construct out of it is not

403
00:15:19,430 --> 00:15:17,519
a length it's a surface and if I give

404
00:15:22,310 --> 00:15:19,440
you a surface in another length I can

405
00:15:24,769 --> 00:15:22,320
construct a volume

406
00:15:26,210 --> 00:15:24,779
and if I only have three dimensions I'm

407
00:15:27,650 --> 00:15:26,220
done right because if you now give me

408
00:15:29,750 --> 00:15:27,660
another length there's nothing I can do

409
00:15:31,430 --> 00:15:29,760
if it's a four-dimensional space okay I

410
00:15:35,509 --> 00:15:31,440
could make a hyper volume and if it's

411
00:15:39,110 --> 00:15:35,519
five dimensional space and so on but um

412
00:15:41,269 --> 00:15:39,120
I a lot of what happens

413
00:15:43,310 --> 00:15:41,279

in physics

414
00:15:46,970 --> 00:15:43,320
uh you don't go up above the

415
00:15:49,610 --> 00:15:46,980
dimensionality of the space and so

416
00:15:52,610 --> 00:15:49,620
basically what I've been playing with

417
00:15:54,590 --> 00:15:52,620
which is I think uh

418
00:15:55,850 --> 00:15:54,600
I don't know if it's an original idea

419
00:15:58,189 --> 00:15:55,860
but it's certainly not one that's been

420
00:16:00,769 --> 00:15:58,199
much investigated is something I call

421
00:16:02,030 --> 00:16:00,779
full discrete geometry and the full

422
00:16:04,670 --> 00:16:02,040
means

423
00:16:06,470 --> 00:16:04,680
you have Zero Dimensional things points

424
00:16:08,329 --> 00:16:06,480
you have one dimensional Atomic things

425
00:16:10,850 --> 00:16:08,339
you can think of as lines you have two

426
00:16:12,949 --> 00:16:10,860
dimensional Atomic things Atomic

427
00:16:15,410 --> 00:16:12,959
surfaces you three-dimensional Atomic

428
00:16:17,150 --> 00:16:15,420
things Atomic volumes okay and if it's a

429
00:16:19,790 --> 00:16:17,160
three-dimensional space then you've got

430
00:16:20,629 --> 00:16:19,800
those things to play with

431
00:16:23,269 --> 00:16:20,639
um

432
00:16:25,250 --> 00:16:23,279
and so you can't just keep whereas if

433
00:16:26,689 --> 00:16:25,260
you have numbers again I can just take a

434
00:16:28,009 --> 00:16:26,699
number and multiply it by itself and

435
00:16:29,629 --> 00:16:28,019
then again and then again and then again

436
00:16:31,850 --> 00:16:29,639
and then again as many times as I want

437
00:16:34,250 --> 00:16:31,860
and I'll still have a number I never you

438
00:16:37,610 --> 00:16:34,260

know the multiplication operation

439
00:16:40,730 --> 00:16:37,620
can be it's a binary operation but it

440
00:16:42,710 --> 00:16:40,740
extended to any to multiplying any any

441
00:16:43,670 --> 00:16:42,720
number of numbers right any final

442
00:16:45,889 --> 00:16:43,680
numbers

443
00:16:47,689 --> 00:16:45,899
there's no way that when you multiply

444
00:16:49,850 --> 00:16:47,699
outside of the dimension so it should

445
00:16:51,710 --> 00:16:49,860
jump out but instead it goes back to the

446
00:16:53,629 --> 00:16:51,720
beginning no no it's just not it's just

447
00:16:56,350 --> 00:16:53,639
not a defined operation because the

448
00:16:59,090 --> 00:16:56,360
operation again the the the the

449
00:17:01,370 --> 00:16:59,100
operation is one that for example can

450
00:17:03,410 --> 00:17:01,380
take two one-dimensional elements and

451
00:17:05,329 --> 00:17:03,420
give you back a two-dimensional element

452
00:17:06,949 --> 00:17:05,339
and it can take a one-dimensional

453
00:17:08,150 --> 00:17:06,959
element in a two-dimensional element and

454
00:17:09,890 --> 00:17:08,160
give you back a three-dimensional

455
00:17:11,210 --> 00:17:09,900
element but if you give it something

456
00:17:12,650 --> 00:17:11,220
else it can't give you anything back

457
00:17:14,630 --> 00:17:12,660
because there are no four-dimensional

458
00:17:16,429 --> 00:17:14,640
elements or five dimensional right so it

459
00:17:18,350 --> 00:17:16,439
just doesn't have you know it's not that

460
00:17:20,350 --> 00:17:18,360
it recycles back or anything it's just

461
00:17:22,370 --> 00:17:20,360
not a defined operation

462
00:17:23,929 --> 00:17:22,380
now when you say that there are no

463
00:17:25,730 --> 00:17:23,939

four-dimensional nor five-dimensional

464
00:17:27,470 --> 00:17:25,740
which means in the theory that you're

465
00:17:29,450 --> 00:17:27,480
constructing what you would like would

466
00:17:31,130 --> 00:17:29,460
to be to in this manifest image of

467
00:17:34,130 --> 00:17:31,140
three-dimensional space you want to get

468
00:17:37,130 --> 00:17:34,140
back to that rather than say something

469
00:17:39,770 --> 00:17:37,140
that's a bit more outrageous or unproven

470
00:17:42,230 --> 00:17:39,780
or right no I mean look the formal

471
00:17:44,570 --> 00:17:42,240
Theory can handle four-dimensional

472
00:17:46,970 --> 00:17:44,580
spaces five dimensional spaces a million

473
00:17:48,710 --> 00:17:46,980
dimensional spaces right 11 dimensional

474
00:17:50,870 --> 00:17:48,720
space you want to do String Theory it's

475
00:17:53,289 --> 00:17:50,880
not that the it's not that the formal

476
00:17:55,270 --> 00:17:53,299
apparatus is limited

477
00:17:58,549 --> 00:17:55,280
but

478
00:18:00,590 --> 00:17:58,559
you're you'd make a decision okay I'm

479
00:18:02,150 --> 00:18:00,600
going to look at two-dimensional

480
00:18:03,590 --> 00:18:02,160
geometry or I'm going to look at

481
00:18:05,390 --> 00:18:03,600
three-dimensional geometry I'm going to

482
00:18:07,010 --> 00:18:05,400
look at 12 dimensional gear all right

483
00:18:10,669 --> 00:18:07,020
right and once you make that decision

484
00:18:14,210 --> 00:18:12,710
let me just lay out some thoughts so

485
00:18:15,650 --> 00:18:14,220
firstly you make a reference to number

486
00:18:17,150 --> 00:18:15,660
there by saying three-dimensional or

487
00:18:19,250 --> 00:18:17,160
four-dimensional and this is strange

488
00:18:21,110 --> 00:18:19,260

because you're trying to build a world

489
00:18:22,970 --> 00:18:21,120
without numbers but then we need a

490
00:18:24,890 --> 00:18:22,980
number in order to specify this world so

491
00:18:26,990 --> 00:18:24,900
how does that work so that that works

492
00:18:29,210 --> 00:18:27,000
because the the Greek numbers the

493
00:18:30,890 --> 00:18:29,220
counting numbers are perfectly fine if

494
00:18:32,870 --> 00:18:30,900
you've got something to count right it's

495
00:18:33,890 --> 00:18:32,880
not that I it's not that I hate all

496
00:18:36,110 --> 00:18:33,900
numbers

497
00:18:37,909 --> 00:18:36,120
um if okay I can say there are two

498
00:18:40,070 --> 00:18:37,919
chairs in the room because you know I'm

499
00:18:42,350 --> 00:18:40,080
just counting one two

500
00:18:44,830 --> 00:18:42,360
um but what happened historically of

501
00:18:47,510 --> 00:18:44,840
course if you want to convert geometry

502
00:18:48,710 --> 00:18:47,520
into arithmetic you need more than the

503
00:18:50,990 --> 00:18:48,720
counting numbers

504
00:18:53,330 --> 00:18:51,000
and if you look back at the history of

505
00:18:55,130 --> 00:18:53,340
it it's very interesting

506
00:18:58,070 --> 00:18:55,140
um the Greeks really only recognized

507
00:19:00,590 --> 00:18:58,080
officially the positive integers as

508
00:19:02,210 --> 00:19:00,600
numbers then you can push a little and

509
00:19:04,970 --> 00:19:02,220
try and convince people there are these

510
00:19:07,789 --> 00:19:04,980
things that you call rational numbers

511
00:19:11,750 --> 00:19:07,799
and that had a little bit of resistance

512
00:19:13,070 --> 00:19:11,760
to it but not too bad then well you

513
00:19:14,990 --> 00:19:13,080

could there are two things you have to

514
00:19:16,669 --> 00:19:15,000
do you eventually have to go to the

515
00:19:18,710 --> 00:19:16,679
irrational numbers if you want to do

516
00:19:20,029 --> 00:19:18,720
euclidean geometry that had a lot of

517
00:19:21,470 --> 00:19:20,039
resistance to it right there are people

518
00:19:23,450 --> 00:19:21,480
who said no those don't make any sense

519
00:19:25,850 --> 00:19:23,460
because if I try and express them in

520
00:19:29,090 --> 00:19:25,860
decimal form it goes on forever it gets

521
00:19:31,010 --> 00:19:29,100
lost in infinity and and then you also

522
00:19:32,690 --> 00:19:31,020
need the negative numbers which you know

523
00:19:34,909 --> 00:19:32,700
there were people who were very upset

524
00:19:36,529 --> 00:19:34,919
about that and you can see why right I

525
00:19:38,330 --> 00:19:36,539
mean you said look okay I understand

526
00:19:39,770 --> 00:19:38,340
what you mean when you say you have two

527
00:19:41,810 --> 00:19:39,780
sheep I understand what you mean even

528
00:19:43,490 --> 00:19:41,820
when you say you have zero sheep but

529
00:19:45,470 --> 00:19:43,500
what would it be to have negative two

530
00:19:47,930 --> 00:19:45,480
sheep right right

531
00:19:51,950 --> 00:19:47,940
um there there can't be less than zero

532
00:19:53,690 --> 00:19:51,960
so negative numbers and it's just in the

533
00:19:55,250 --> 00:19:53,700
record in the historical record there

534
00:19:56,090 --> 00:19:55,260
was a lot of resistance to negative

535
00:19:59,230 --> 00:19:56,100
numbers

536
00:20:03,110 --> 00:19:59,240
so I don't have any problem with

537
00:20:05,630 --> 00:20:03,120
integers if you have something to count

538
00:20:07,490 --> 00:20:05,640

and and the counting measure in this

539
00:20:10,010 --> 00:20:07,500
discrete geometry you use counting

540
00:20:13,430 --> 00:20:10,020
measure because you have a finite number

541
00:20:16,070 --> 00:20:13,440
of points or a finite number of lines or

542
00:20:18,409 --> 00:20:16,080
a finite number of surfaces in a certain

543
00:20:20,690 --> 00:20:18,419
situation and you can just count them

544
00:20:22,549 --> 00:20:20,700
and the counting is important so it's

545
00:20:25,130 --> 00:20:22,559
not that I hate all numbers

546
00:20:26,690 --> 00:20:25,140
I just when you use numbers you should

547
00:20:28,549 --> 00:20:26,700
ask yourself okay where are the numbers

548
00:20:30,710 --> 00:20:28,559
coming from if they're coming from

549
00:20:32,630 --> 00:20:30,720
Counting something discrete okay that's

550
00:20:34,430 --> 00:20:32,640
a good answer

551
00:20:38,450 --> 00:20:34,440
if they're not

552
00:20:40,430 --> 00:20:38,460
then you need a fancier story about why

553
00:20:41,870 --> 00:20:40,440
you're using them at all let's get

554
00:20:43,730 --> 00:20:41,880
quickly philosophical if you don't mind

555
00:20:45,289 --> 00:20:43,740
and then I want to get to your views on

556
00:20:46,430 --> 00:20:45,299
quantum mechanics there's different

557
00:20:48,350 --> 00:20:46,440
theories of Truth so there's

558
00:20:50,750 --> 00:20:48,360
correspondence coherence and pragmatism

559
00:20:52,669 --> 00:20:50,760
are the main three

560
00:20:54,950 --> 00:20:52,679
for the correspondence this just made me

561
00:20:56,750 --> 00:20:54,960
think well in the correspondence theory

562
00:20:58,669 --> 00:20:56,760
of Truth could there be minus two

563
00:21:00,289 --> 00:20:58,679

because minus two wouldn't correspond to

564
00:21:02,570 --> 00:21:00,299
something of the world but then it seems

565
00:21:03,950 --> 00:21:02,580
strange because many people who say I

566
00:21:06,230 --> 00:21:03,960
believe in the correspondence theory of

567
00:21:08,150 --> 00:21:06,240
Truth are perfectly fine using numbers

568
00:21:10,130 --> 00:21:08,160
real numbers I never thought about that

569
00:21:12,409 --> 00:21:10,140
what does the correspondence theory of

570
00:21:14,330 --> 00:21:12,419
Truth have to say about

571
00:21:17,570 --> 00:21:14,340
real numbers or even complex numbers

572
00:21:19,310 --> 00:21:17,580
well okay so the the I think the

573
00:21:21,430 --> 00:21:19,320
difficulty you're having is that you're

574
00:21:24,169 --> 00:21:21,440
touching on an extremely

575
00:21:26,750 --> 00:21:24,179
extremely difficult subject

576
00:21:29,210 --> 00:21:26,760
um and one about which I don't have much

577
00:21:32,510 --> 00:21:29,220
to say because it's too deep for me and

578
00:21:34,909 --> 00:21:32,520
that's the ontology of mathematics

579
00:21:38,149 --> 00:21:34,919
that's mathematical reality

580
00:21:40,730 --> 00:21:38,159
so if I'm a if I'm in some intuitive

581
00:21:43,190 --> 00:21:40,740
sense a correspondence theorist

582
00:21:44,810 --> 00:21:43,200
I say look at least for certain

583
00:21:47,090 --> 00:21:44,820
sentences

584
00:21:49,789 --> 00:21:47,100
what makes that sentence either true or

585
00:21:51,610 --> 00:21:49,799
false is whether it correctly or

586
00:21:53,870 --> 00:21:51,620
incorrectly describes some

587
00:21:55,010 --> 00:21:53,880
non-linguistic thing right the subject

588
00:21:59,330 --> 00:21:55,020

matter

589
00:22:01,970 --> 00:21:59,340
the physical world so we kind of know at

590
00:22:04,789 --> 00:22:01,980
least what the target is but but

591
00:22:06,890 --> 00:22:04,799
mathematical items as as Plato pointed

592
00:22:09,590 --> 00:22:06,900
out are not physical items

593
00:22:12,350 --> 00:22:09,600
so if you want to be a basically a

594
00:22:14,149 --> 00:22:12,360
correspondence theorist as I do you're

595
00:22:16,490 --> 00:22:14,159
naturally going to be a platonist in

596
00:22:18,770 --> 00:22:16,500
mathematics which I am right that is I

597
00:22:21,649 --> 00:22:18,780
am I I think they're mathematical truths

598
00:22:24,409 --> 00:22:21,659
and if you ask what makes them true the

599
00:22:26,029 --> 00:22:24,419
answer is well mathematical reality and

600
00:22:27,230 --> 00:22:26,039
if you ask me what mathematical reality

601
00:22:29,570 --> 00:22:27,240
is I'm going to say well it isn't

602
00:22:30,169 --> 00:22:29,580
physical reality for sure

603
00:22:33,409 --> 00:22:30,179
um

604
00:22:36,890 --> 00:22:33,419
it has its own kind of existence very

605
00:22:39,049 --> 00:22:36,900
much the way Plato would say and there

606
00:22:41,390 --> 00:22:39,059
are facts about it and some of the facts

607
00:22:44,570 --> 00:22:41,400
we can discover and some of them will

608
00:22:46,669 --> 00:22:44,580
never discover is girdle assures us

609
00:22:49,010 --> 00:22:46,679
um okay that's fine there's a world that

610
00:22:50,990 --> 00:22:49,020
has more facts about it than we're able

611
00:22:52,549 --> 00:22:51,000
to to to to just it's kind of amazing we

612
00:22:54,049 --> 00:22:52,559
can discover anything about it you know

613
00:22:56,029 --> 00:22:54,059

I shouldn't be very surprised I can't

614
00:22:58,490 --> 00:22:56,039
discover everything about it

615
00:23:01,250 --> 00:22:58,500
um so

616
00:23:02,690 --> 00:23:01,260
what what you're really asking from my

617
00:23:04,909 --> 00:23:02,700
point of view is not about the physical

618
00:23:07,130 --> 00:23:04,919
world at all it's about the nature of

619
00:23:09,830 --> 00:23:07,140
purely mathematical reality

620
00:23:11,750 --> 00:23:09,840
and again I I very firmly believe there

621
00:23:14,570 --> 00:23:11,760
is such a thing and and it's independent

622
00:23:16,130 --> 00:23:14,580
of physical reality right I mean physics

623
00:23:18,230 --> 00:23:16,140
could have come out all kinds of

624
00:23:20,149 --> 00:23:18,240
different ways but however physics came

625
00:23:22,370 --> 00:23:20,159
out it wouldn't change the mathematical

626
00:23:23,750 --> 00:23:22,380
facts at all so physics is dependent on

627
00:23:25,669 --> 00:23:23,760
the mathematical reality but not vice

628
00:23:27,830 --> 00:23:25,679
versa no well no physics is not

629
00:23:30,529 --> 00:23:27,840
dependent on mathematical reality in a

630
00:23:32,930 --> 00:23:30,539
white physics see mathematical physics

631
00:23:36,350 --> 00:23:32,940
is a discipline

632
00:23:38,210 --> 00:23:36,360
that uses mathematical items

633
00:23:39,830 --> 00:23:38,220
to attempt to describe the physical

634
00:23:43,610 --> 00:23:39,840
world

635
00:23:45,470 --> 00:23:43,620
and the mathematical items exist they

636
00:23:46,669 --> 00:23:45,480
are what they are and they are what they

637
00:23:48,710 --> 00:23:46,679
are independently of what we think and

638
00:23:51,289 --> 00:23:48,720

we can find out about them by you know

639
00:23:53,029 --> 00:23:51,299
in a math department you can investigate

640
00:23:55,190 --> 00:23:53,039
the structure of the mathematical items

641
00:23:58,970 --> 00:23:55,200
the Deep question

642
00:24:02,810 --> 00:23:58,980
which is always there is why should

643
00:24:05,770 --> 00:24:02,820
these mathematical items serve as good

644
00:24:09,049 --> 00:24:05,780
representations of physical reality

645
00:24:12,049 --> 00:24:09,059
now this is where I would say

646
00:24:15,049 --> 00:24:12,059
again for many numbers I'm puzzled white

647
00:24:17,330 --> 00:24:15,059
why why am I using numbers anyway for

648
00:24:19,970 --> 00:24:17,340
certain geometrical things again purely

649
00:24:22,970 --> 00:24:19,980
abstract mathematical geometrical things

650
00:24:24,529 --> 00:24:22,980
it seems to me perfectly plausible to

651
00:24:26,930 --> 00:24:24,539
say Well they're good because the

652
00:24:29,210 --> 00:24:26,940
physical world literally has a

653
00:24:30,649 --> 00:24:29,220
geometrical structure

654
00:24:32,630 --> 00:24:30,659
um you know Newton thought that space

655
00:24:34,330 --> 00:24:32,640
was a three-dimensional euclidean how do

656
00:24:37,190 --> 00:24:34,340
you three-dimensional euclidean space

657
00:24:39,289 --> 00:24:37,200
structure and it could have had it turns

658
00:24:41,570 --> 00:24:39,299
out not to have but it could have had

659
00:24:44,630 --> 00:24:41,580
and if it did have then you'd perfectly

660
00:24:47,570 --> 00:24:44,640
well understand why euclidean geometry

661
00:24:49,090 --> 00:24:47,580
which remains a perfectly good

662
00:24:53,270 --> 00:24:49,100
mathematical

663
00:24:54,770 --> 00:24:53,280

investigation into euclidean's Pace you

664
00:24:57,470 --> 00:24:54,780
would understand why it has so much

665
00:24:59,390 --> 00:24:57,480
utility for physics

666
00:25:01,789 --> 00:24:59,400
um three-dimensional euclidean geometry

667
00:25:05,149 --> 00:25:01,799
right I mean 10 dimensional euclidean

668
00:25:07,250 --> 00:25:05,159
geometry exists just as well abstractly

669
00:25:09,710 --> 00:25:07,260
as three-dimensional euclidean geometry

670
00:25:11,930 --> 00:25:09,720
but it might have no use in physics

671
00:25:14,029 --> 00:25:11,940
because actual physical space is not 10

672
00:25:16,730 --> 00:25:14,039
dimensional

673
00:25:19,549 --> 00:25:16,740
when I think about platonism I think of

674
00:25:21,409 --> 00:25:19,559
it as being extremely mystically

675
00:25:23,510 --> 00:25:21,419
religious and I don't have any I don't

676
00:25:25,789 --> 00:25:23,520
score in it for being so and I think

677
00:25:27,590 --> 00:25:25,799
Plato thought of the forms of something

678
00:25:29,750 --> 00:25:27,600
mystical as well something related to

679
00:25:31,970 --> 00:25:29,760
God I can ask your thoughts on that but

680
00:25:34,010 --> 00:25:31,980
what I wanted to say was more about it's

681
00:25:35,570 --> 00:25:34,020
strange because you were saying that the

682
00:25:38,450 --> 00:25:35,580
physical reality doesn't depend on the

683
00:25:40,370 --> 00:25:38,460
mathematical However the fact that we

684
00:25:42,230 --> 00:25:40,380
can use it it gives some visual analogy

685
00:25:43,669 --> 00:25:42,240
it's as if we're these physical beings

686
00:25:45,049 --> 00:25:43,679
and we can reach into the closet of

687
00:25:48,110 --> 00:25:45,059
mathematics and pull out something and

688
00:25:49,669 --> 00:25:48,120

then use it as a tool here

689
00:25:51,350 --> 00:25:49,679
it doesn't seem like the mathematics

690
00:25:52,789 --> 00:25:51,360
reaches into us and then uses it there

691
00:25:54,590 --> 00:25:52,799
although perhaps it doesn't we don't

692
00:25:57,230 --> 00:25:54,600
know so it seems like

693
00:25:58,610 --> 00:25:57,240
that's a world that we pull from now how

694
00:26:01,010 --> 00:25:58,620
can we so is there an interaction

695
00:26:03,950 --> 00:26:01,020
between these two worlds quite there's a

696
00:26:06,710 --> 00:26:03,960
huge turn in Plato the the turn between

697
00:26:09,649 --> 00:26:06,720
the early and the middle dialogues which

698
00:26:13,070 --> 00:26:09,659
is indicated in in meno

699
00:26:15,430 --> 00:26:13,080
and in Nino is where you you have a kind

700
00:26:18,110 --> 00:26:15,440
of standard Socratic

701
00:26:19,549 --> 00:26:18,120
dialogue cross-examining Nino and

702
00:26:22,970 --> 00:26:19,559
showing that he doesn't really know what

703
00:26:24,470 --> 00:26:22,980
virtue is what arate is and then he gets

704
00:26:26,570 --> 00:26:24,480
all messed up and says I have nothing

705
00:26:28,130 --> 00:26:26,580
more to say and Socrates says well why

706
00:26:30,289 --> 00:26:28,140
don't we keep talking

707
00:26:31,490 --> 00:26:30,299
Amino quite reasonably says wait a

708
00:26:33,169 --> 00:26:31,500
minute you tell me you don't know what

709
00:26:34,669 --> 00:26:33,179
virtue is and I now don't know what

710
00:26:36,590 --> 00:26:34,679
virtue is why should we keep discovering

711
00:26:39,529 --> 00:26:36,600
we're too ignoramuses why should we keep

712
00:26:41,210 --> 00:26:39,539
with each other and and Socrates says

713
00:26:42,830 --> 00:26:41,220

well you know and then he kind of

714
00:26:44,690 --> 00:26:42,840
indicates the theory of reminiscence but

715
00:26:47,870 --> 00:26:44,700
the important point is he then brings

716
00:26:50,630 --> 00:26:47,880
out this mathematical question

717
00:26:53,390 --> 00:26:50,640
um if I have a square

718
00:26:56,330 --> 00:26:53,400
say two units on a side so it's four

719
00:26:58,789 --> 00:26:56,340
square it's area is four square units

720
00:27:01,070 --> 00:26:58,799
and I want to build a double square that

721
00:27:02,690 --> 00:27:01,080
is one whose area is twice as big eight

722
00:27:03,350 --> 00:27:02,700
units

723
00:27:07,010 --> 00:27:03,360
um

724
00:27:09,590 --> 00:27:07,020
along which what line do I build it

725
00:27:11,570 --> 00:27:09,600
so that's a perfectly good question and

726
00:27:13,190 --> 00:27:11,580
he brings this slave over who's not

727
00:27:14,450 --> 00:27:13,200
learned any geometry and the slave

728
00:27:16,789 --> 00:27:14,460
starts out

729
00:27:18,830 --> 00:27:16,799
saying oh you double the side and then

730
00:27:20,390 --> 00:27:18,840
he points out they do some counting and

731
00:27:22,430 --> 00:27:20,400
say no that's not right that gives me

732
00:27:23,930 --> 00:27:22,440
16. then he says well let's try three

733
00:27:25,669 --> 00:27:23,940
well that doesn't work that gives me not

734
00:27:28,909 --> 00:27:25,679
and then the slave says I don't know

735
00:27:31,250 --> 00:27:28,919
right and then Socrates draws in you

736
00:27:33,769 --> 00:27:31,260
know the diagonals and and again they

737
00:27:35,690 --> 00:27:33,779
just count and easily show that the

738
00:27:37,669 --> 00:27:35,700

square on the diagonal has twice the

739
00:27:39,289 --> 00:27:37,679
area now I don't think the thing in the

740
00:27:42,590 --> 00:27:39,299
world mystical about it's the opposite

741
00:27:46,390 --> 00:27:42,600
of mystical right mystical suggests some

742
00:27:52,430 --> 00:27:48,169
presentation

743
00:27:55,549 --> 00:27:52,440
that you believe without reason

744
00:27:57,769 --> 00:27:55,559
right and this is just the opposite the

745
00:28:00,289 --> 00:27:57,779
reason you believe that the square on

746
00:28:02,210 --> 00:28:00,299
the diagonal has twice the area is

747
00:28:03,950 --> 00:28:02,220
you've got a proof

748
00:28:05,870 --> 00:28:03,960
right that's what you could gives you

749
00:28:09,289 --> 00:28:05,880
he's not a Mystic right Euclid's not a

750
00:28:11,269 --> 00:28:09,299
Mystic he's a guy who can prove it

751
00:28:12,230 --> 00:28:11,279
so you know and that's what's

752
00:28:14,870 --> 00:28:12,240
interesting I mean the thing that

753
00:28:18,110 --> 00:28:14,880
interested Plato is look I can actually

754
00:28:20,750 --> 00:28:18,120
literally know things about geometrical

755
00:28:23,390 --> 00:28:20,760
figures know them have proofs of them

756
00:28:27,409 --> 00:28:23,400
have demonstrations know what the truth

757
00:28:29,390 --> 00:28:27,419
is and he says in timeus

758
00:28:31,250 --> 00:28:29,400
which is the closest he comes to giving

759
00:28:34,610 --> 00:28:31,260
us a physics

760
00:28:36,470 --> 00:28:34,620
paimaeus does uh he says look don't

761
00:28:38,510 --> 00:28:36,480
expect that kind of knowledge of the

762
00:28:40,490 --> 00:28:38,520
physical world the best you can expect

763
00:28:42,529 --> 00:28:40,500

of the physical world is what he calls

764
00:28:45,649 --> 00:28:42,539
an echos logos which is a plausible

765
00:28:47,510 --> 00:28:45,659
story right a likely account a plausible

766
00:28:51,230 --> 00:28:47,520
story and I'll give you a plausible

767
00:28:53,630 --> 00:28:51,240
story but I can't prove that it's right

768
00:28:57,409 --> 00:28:53,640
um so Plato just recognized correctly

769
00:28:58,789 --> 00:28:57,419
that we have much better epistemic

770
00:29:06,049 --> 00:28:58,799
access

771
00:29:07,610 --> 00:29:06,059
to mathematics than we do to physics and

772
00:29:09,649 --> 00:29:07,620
that's not because he's a Mystic it's

773
00:29:11,029 --> 00:29:09,659
it's the opposite he's kind of a hyper

774
00:29:13,430 --> 00:29:11,039
rationalist

775
00:29:15,950 --> 00:29:13,440
okay so two thoughts and I don't know if

776
00:29:17,750 --> 00:29:15,960
this is apocryphal or not but Pythagoras

777
00:29:19,610 --> 00:29:17,760
at least repeatedly said that there is

778
00:29:22,070 --> 00:29:19,620
something ill about the square root of

779
00:29:23,810 --> 00:29:22,080
two no you didn't I'm sorry

780
00:29:26,210 --> 00:29:23,820
okay so at least infamously infamously

781
00:29:28,070 --> 00:29:26,220
or reputed yeah this is a this is a fake

782
00:29:29,570 --> 00:29:28,080
story interested in the truth here

783
00:29:32,269 --> 00:29:29,580
there's a wonderful book called The

784
00:29:33,710 --> 00:29:32,279
mathematics of Plato's academy by Donald

785
00:29:34,850 --> 00:29:33,720
Fowler

786
00:29:36,830 --> 00:29:34,860
um

787
00:29:40,130 --> 00:29:36,840
which goes through all this that this

788
00:29:41,649 --> 00:29:40,140

whole that the pythagoreans were really

789
00:29:44,330 --> 00:29:41,659
um yeah there's a lot of propag

790
00:29:46,430 --> 00:29:44,340
anti-pythagorean propaganda it's it's

791
00:29:48,470 --> 00:29:46,440
actually quite unclear in the historical

792
00:29:50,690 --> 00:29:48,480
record what the pythagoreans believed

793
00:29:52,990 --> 00:29:50,700
but what is clear is that nobody was

794
00:29:56,149 --> 00:29:53,000
worried about the square root of well

795
00:29:58,490 --> 00:29:56,159
again let me even be more precise

796
00:30:00,470 --> 00:29:58,500
when we say

797
00:30:03,470 --> 00:30:00,480
there was an issue about the square root

798
00:30:04,610 --> 00:30:03,480
of two we mean by the square root of two

799
00:30:07,930 --> 00:30:04,620
a number

800
00:30:10,850 --> 00:30:07,940
let's go back again right

801
00:30:12,769 --> 00:30:10,860
1.414. yeah

802
00:30:14,510 --> 00:30:12,779
the Greeks did not recognize the

803
00:30:16,610 --> 00:30:14,520
existence of any such number they didn't

804
00:30:18,669 --> 00:30:16,620
believe there was any number which if

805
00:30:20,630 --> 00:30:18,679
you multiplied it by itself you got two

806
00:30:22,730 --> 00:30:20,640
why because they thought the numbers

807
00:30:24,470 --> 00:30:22,740
were the were the counting numbers and

808
00:30:26,210 --> 00:30:24,480
obviously you can't

809
00:30:29,029 --> 00:30:26,220
square and you can't multiply any

810
00:30:32,870 --> 00:30:29,039
counting number by itself and get two

811
00:30:35,870 --> 00:30:32,880
now what they did recognize by a very

812
00:30:37,370 --> 00:30:35,880
interesting geometrical proof is that if

813
00:30:39,590 --> 00:30:37,380

you have a square

814
00:30:43,250 --> 00:30:39,600
and you have its side and you have its

815
00:30:47,990 --> 00:30:43,260
diagonal that those are in commensurable

816
00:30:51,049 --> 00:30:48,000
that is that the length of one cannot be

817
00:30:52,490 --> 00:30:51,059
expressed as a ratio in terms of the

818
00:30:54,590 --> 00:30:52,500
length of the other

819
00:30:56,630 --> 00:30:54,600
now that doesn't pick out the diagonal

820
00:31:00,529 --> 00:30:56,640
as the bad guy or the side is the square

821
00:31:03,409 --> 00:31:00,539
bad guy in commensurability of that sort

822
00:31:05,750 --> 00:31:03,419
is a is a relation between two lengths

823
00:31:07,430 --> 00:31:05,760
it doesn't say oh you know the side is

824
00:31:09,490 --> 00:31:07,440
good and the diagonal is bad or anything

825
00:31:12,889 --> 00:31:09,500
like that it just says

826
00:31:14,570 --> 00:31:12,899
these the ratio of lengths between the

827
00:31:17,570 --> 00:31:14,580
side and the diagonal does not

828
00:31:20,330 --> 00:31:17,580
correspond to the ratio between any two

829
00:31:23,630 --> 00:31:20,340
integers that's what they knew

830
00:31:25,190 --> 00:31:23,640
but it didn't seem to bother them

831
00:31:26,810 --> 00:31:25,200
um in fact they thought it was quite

832
00:31:31,669 --> 00:31:26,820
interesting there was a whole there was

833
00:31:34,549 --> 00:31:31,679
a a um a whole terminology about all

834
00:31:36,649 --> 00:31:34,559
about links that are all logon

835
00:31:38,810 --> 00:31:36,659
which would be like these that can't be

836
00:31:40,970 --> 00:31:38,820
expressed in terms of ratios and and

837
00:31:43,549 --> 00:31:40,980
they had further subdivisions among them

838
00:31:46,190 --> 00:31:43,559

and nobody was upset about it

839
00:31:48,230 --> 00:31:46,200
just an interesting fact

840
00:31:51,230 --> 00:31:48,240
what led you down this route of trying

841
00:31:53,090 --> 00:31:51,240
to make geometry Primal like underived

842
00:31:55,669 --> 00:31:53,100
elements of reality

843
00:31:58,789 --> 00:31:55,679
just mostly the thought that I could

844
00:32:02,210 --> 00:31:58,799
understand I could I could see how

845
00:32:04,010 --> 00:32:02,220
a geometrical representation could in

846
00:32:05,930 --> 00:32:04,020
principle more or less directly

847
00:32:08,029 --> 00:32:05,940
correspond to the structure of the world

848
00:32:10,370 --> 00:32:08,039
that the world the physical world sorry

849
00:32:12,710 --> 00:32:10,380
that the physical world could literally

850
00:32:14,510 --> 00:32:12,720
have a geometrical structure

851
00:32:16,669 --> 00:32:14,520
and I don't understand how the physical

852
00:32:18,769 --> 00:32:16,679
world could literally have an algebraic

853
00:32:21,409 --> 00:32:18,779
structure

854
00:32:24,049 --> 00:32:21,419
so I I'd like to get along as much as I

855
00:32:26,450 --> 00:32:24,059
can with geometry this word geometry is

856
00:32:28,909 --> 00:32:26,460
interesting when I was in university I

857
00:32:30,350 --> 00:32:28,919
always thought of geometry as I forgot

858
00:32:32,750 --> 00:32:30,360
the exact name but I took some course

859
00:32:34,610 --> 00:32:32,760
where it's almost like euclidean

860
00:32:36,529 --> 00:32:34,620
geometry or it is euclidean geometry and

861
00:32:37,850 --> 00:32:36,539
there was inversions I had to do some

862
00:32:39,769 --> 00:32:37,860
problem with inversions this is all I

863
00:32:41,870 --> 00:32:39,779

remember what is that called analytic

864
00:32:44,750 --> 00:32:41,880
geometry is there some word for it like

865
00:32:46,669 --> 00:32:44,760
planar geometry something like that I

866
00:32:48,350 --> 00:32:46,679
mean I I'm yeah I'm not exactly sure

867
00:32:51,230 --> 00:32:48,360
okay well anyway it's with what you

868
00:32:53,149 --> 00:32:51,240
construct with lines and circles and

869
00:32:55,130 --> 00:32:53,159
then there's differential geometry and

870
00:32:57,889 --> 00:32:55,140
to me I see that as extremely algebraic

871
00:32:59,049 --> 00:32:57,899
firstly it's also contingent on the real

872
00:33:01,970 --> 00:32:59,059
numbers

873
00:33:06,950 --> 00:33:01,980
differential geometry is basically what

874
00:33:10,250 --> 00:33:06,960
you use when the geometrical structure

875
00:33:11,990 --> 00:33:10,260
changes from place to place so in

876
00:33:14,149 --> 00:33:12,000
euclidean Geometry you have all these

877
00:33:17,210 --> 00:33:14,159
nice symmetries right the the the the

878
00:33:19,549 --> 00:33:17,220
the structure of euclidean space

879
00:33:20,870 --> 00:33:19,559
is the same everywhere

880
00:33:22,970 --> 00:33:20,880
so there's kind of translational

881
00:33:24,350 --> 00:33:22,980
symmetries and it's the same in all

882
00:33:27,049 --> 00:33:24,360
directions so they're rotational

883
00:33:29,210 --> 00:33:27,059
symmetries right it's actually the same

884
00:33:31,250 --> 00:33:29,220
even under expansions and contractions

885
00:33:35,570 --> 00:33:31,260
which is really unusual that's not true

886
00:33:37,970 --> 00:33:35,580
in in in even a space of uniform

887
00:33:40,730 --> 00:33:37,980
curvature so it has all these nice

888
00:33:42,289 --> 00:33:40,740

symmetries but you could be living in a

889
00:33:44,570 --> 00:33:42,299
world where the geometry just doesn't

890
00:33:46,610 --> 00:33:44,580
have these nice symmetries and then the

891
00:33:47,870 --> 00:33:46,620
geometrical structure changes from place

892
00:33:49,909 --> 00:33:47,880
to place and then you have to use

893
00:33:52,490 --> 00:33:49,919
differential geometry which just means

894
00:33:55,310 --> 00:33:52,500
that you you characterize the geometry

895
00:33:56,630 --> 00:33:55,320
local in some little region and then in

896
00:33:58,970 --> 00:33:56,640
the next one and then in the next one

897
00:34:01,549 --> 00:33:58,980
with all these little overlapping maps

898
00:34:03,769 --> 00:34:01,559
that cover the different regions and and

899
00:34:05,810 --> 00:34:03,779
you don't have a constraint that the

900
00:34:08,570 --> 00:34:05,820
geometry looks the same

901
00:34:10,790 --> 00:34:08,580
in all the regions now none of that

902
00:34:12,530 --> 00:34:10,800
suggests using numbers

903
00:34:14,990 --> 00:34:12,540
and it doesn't you don't need to use

904
00:34:16,490 --> 00:34:15,000
numbers I mean you numbers tend to get

905
00:34:18,710 --> 00:34:16,500
in again with you when you introduce

906
00:34:20,510 --> 00:34:18,720
coordinates but they're coordinate free

907
00:34:23,629 --> 00:34:20,520
characterizations

908
00:34:26,930 --> 00:34:23,639
of all of this of all of this geometry

909
00:34:29,389 --> 00:34:26,940
so you don't need and as I said if the

910
00:34:33,829 --> 00:34:29,399
space is curved then no coordinate

911
00:34:36,950 --> 00:34:33,839
systems will be particularly great right

912
00:34:39,589 --> 00:34:36,960
um the nice thing about a a spaces of

913
00:34:41,750 --> 00:34:39,599

constant curvature and especially zero

914
00:34:43,550 --> 00:34:41,760
curvature is that there are these nice

915
00:34:45,530 --> 00:34:43,560
coordinate systems like Cartesian

916
00:34:47,149 --> 00:34:45,540
coordinates so forgive me because it's

917
00:34:49,550 --> 00:34:47,159
been a while since I've been in

918
00:34:52,730 --> 00:34:49,560
University the way that I recall it is

919
00:34:54,169 --> 00:34:52,740
that you define a smooth structure by

920
00:34:55,250 --> 00:34:54,179
saying that so and so is infinitely

921
00:34:57,050 --> 00:34:55,260
differentiable to Define

922
00:34:58,910 --> 00:34:57,060
differentiability you have to say that

923
00:35:00,410 --> 00:34:58,920
it goes from the reels to the reels I'm

924
00:35:02,450 --> 00:35:00,420
sure you have some chart in between it's

925
00:35:05,270 --> 00:35:02,460
like RN but somehow you have a curve

926
00:35:07,070 --> 00:35:05,280
that's R to the m so R to the manifold

927
00:35:09,890 --> 00:35:07,080
and then from the manifold down to a

928
00:35:11,690 --> 00:35:09,900
chart so you require the reels here then

929
00:35:13,130 --> 00:35:11,700
the reels on the chart and then you say

930
00:35:15,650 --> 00:35:13,140
it's differentiable based on

931
00:35:17,150 --> 00:35:15,660
differentiability in the reels I don't

932
00:35:18,589 --> 00:35:17,160
know if that's correct please forgive me

933
00:35:20,630 --> 00:35:18,599
if I'm incorrect no no that's the normal

934
00:35:22,430 --> 00:35:20,640
way it's presented I mean what you said

935
00:35:26,510 --> 00:35:22,440
is perfectly accurate is the way it's

936
00:35:29,450 --> 00:35:26,520
taught that you throw in functions

937
00:35:31,250 --> 00:35:29,460
from the space to the reels or the r to

938
00:35:35,030 --> 00:35:31,260

the end

939
00:35:38,089 --> 00:35:35,040
as part of the story yeah and and then

940
00:35:41,569 --> 00:35:38,099
you talk you you you talk about whether

941
00:35:43,490 --> 00:35:41,579
a function from RN to RN is continuous

942
00:35:45,349 --> 00:35:43,500
and so on

943
00:35:47,750 --> 00:35:45,359
um by appealing to the structure of the

944
00:35:49,130 --> 00:35:47,760
real line that is the usual way it's

945
00:35:50,349 --> 00:35:49,140
presented it doesn't have to be done

946
00:35:53,329 --> 00:35:50,359
that way

947
00:35:55,069 --> 00:35:53,339
and it should be obvious that there's

948
00:35:57,650 --> 00:35:55,079
something quite artificial about it

949
00:35:59,089 --> 00:35:57,660
because if I just have a space in front

950
00:36:01,190 --> 00:35:59,099
of me

951
00:36:03,230 --> 00:36:01,200
where's this function into the real

952
00:36:05,690 --> 00:36:03,240
numbers coming from well it it only

953
00:36:08,510 --> 00:36:05,700
comes by somehow laying down coordinates

954
00:36:10,310 --> 00:36:08,520
which could be done in infinitely many

955
00:36:15,890 --> 00:36:10,320
different ways

956
00:36:22,970 --> 00:36:18,710
um and what you would prefer from as a

957
00:36:25,010 --> 00:36:22,980
pure as a calculational matter

958
00:36:28,250 --> 00:36:25,020
what they're doing is fine because it's

959
00:36:31,490 --> 00:36:28,260
easier to calculate with numbers

960
00:36:33,589 --> 00:36:31,500
as a conceptual matter you're better off

961
00:36:35,930 --> 00:36:33,599
avoiding

962
00:36:38,030 --> 00:36:35,940
this use of numbers where you can

963
00:36:40,370 --> 00:36:38,040

because they're only introduced in a

964
00:36:42,410 --> 00:36:40,380
kind of artificial way

965
00:36:43,970 --> 00:36:42,420
so yeah I mean your your memory of that

966
00:36:46,550 --> 00:36:43,980
is perfectly correct but people people

967
00:36:50,270 --> 00:36:46,560
teaching math are not

968
00:36:53,050 --> 00:36:50,280
I mean especially unless you really go

969
00:36:56,990 --> 00:36:53,060
deep into the foundations of mathematics

970
00:37:00,530 --> 00:36:57,000
they're teaching you a tool

971
00:37:02,450 --> 00:37:00,540
um and when you learn calculus and

972
00:37:04,550 --> 00:37:02,460
Vector calculus and so on they're giving

973
00:37:06,890 --> 00:37:04,560
you a tool for doing calculations and

974
00:37:08,930 --> 00:37:06,900
grinding out answers that's a very

975
00:37:12,109 --> 00:37:08,940
effective tool

976
00:37:13,910 --> 00:37:12,119
um what what happens if you're a

977
00:37:16,250 --> 00:37:13,920
philosopher like me

978
00:37:18,349 --> 00:37:16,260
is that

979
00:37:19,609 --> 00:37:18,359
it's not so interesting learning how to

980
00:37:22,430 --> 00:37:19,619
use the tool I mean when I when I was

981
00:37:23,810 --> 00:37:22,440
doing my PhD in history and philosophy

982
00:37:26,210 --> 00:37:23,820
of science because I was specializing in

983
00:37:27,950 --> 00:37:26,220
physics I did was had to do graduate

984
00:37:31,790 --> 00:37:27,960
level work in physics

985
00:37:35,270 --> 00:37:31,800
and I took one course and I remember you

986
00:37:38,030 --> 00:37:35,280
know perfectly fine horse Physics course

987
00:37:40,310 --> 00:37:38,040
interesting for my purposes interesting

988
00:37:43,250 --> 00:37:40,320

things were said on day one

989
00:37:45,290 --> 00:37:43,260
the first day because it was on the

990
00:37:47,089 --> 00:37:45,300
first day that the the professor was

991
00:37:50,089 --> 00:37:47,099
trying to set up

992
00:37:52,550 --> 00:37:50,099
what are we doing

993
00:37:54,470 --> 00:37:52,560
and then the rest of the course which

994
00:37:56,870 --> 00:37:54,480
was like how to use greens functions to

995
00:37:58,550 --> 00:37:56,880
solve differential equations okay it

996
00:38:01,370 --> 00:37:58,560
didn't matter to me I mean it just it

997
00:38:02,990 --> 00:38:01,380
made no difference for my interests now

998
00:38:04,790 --> 00:38:03,000
if you actually if I needed to get

999
00:38:06,950 --> 00:38:04,800
numbers if I needed to actually grind

1000
00:38:08,390 --> 00:38:06,960
numbers out I really needed to

1001
00:38:10,550 --> 00:38:08,400
understand all the rest of that of

1002
00:38:12,290 --> 00:38:10,560
course but that's not what I do right

1003
00:38:14,990 --> 00:38:12,300
I'm more interested in well why am I

1004
00:38:17,810 --> 00:38:15,000
using numbers anyway

1005
00:38:20,270 --> 00:38:17,820
you know not how exactly do I use them

1006
00:38:23,569 --> 00:38:20,280
or or how do I solve these equations

1007
00:38:25,250 --> 00:38:23,579
right my only rarely once or twice in my

1008
00:38:27,589 --> 00:38:25,260
life if I had to actually solve an

1009
00:38:29,230 --> 00:38:27,599
equation to make progress

1010
00:38:31,790 --> 00:38:29,240
um

1011
00:38:33,770 --> 00:38:31,800
can you give me an instance of them of

1012
00:38:37,430 --> 00:38:33,780
the one or two times where you have to

1013
00:38:39,650 --> 00:38:37,440

use an equation oh yeah I mean I mean I

1014
00:38:42,170 --> 00:38:39,660
I mean I remember this very when my very

1015
00:38:45,109 --> 00:38:42,180
first book which is quantum non-locality

1016
00:38:46,730 --> 00:38:45,119
and relativity there's a

1017
00:38:47,990 --> 00:38:46,740
uh

1018
00:38:50,690 --> 00:38:48,000
there's a

1019
00:38:55,810 --> 00:38:50,700
a chapter which is about

1020
00:39:00,290 --> 00:38:57,950
non-locality violations of Bell's

1021
00:39:03,650 --> 00:39:00,300
inequality through a certain trick which

1022
00:39:05,030 --> 00:39:03,660
involves having uh particles or objects

1023
00:39:07,250 --> 00:39:05,040
that you're observing that just don't

1024
00:39:09,770 --> 00:39:07,260
show up that disappear that never show

1025
00:39:10,849 --> 00:39:09,780
up in the data okay and if you're very

1026
00:39:14,390 --> 00:39:10,859
clever

1027
00:39:16,730 --> 00:39:14,400
you can use this

1028
00:39:19,010 --> 00:39:16,740
Gap in the data

1029
00:39:20,870 --> 00:39:19,020
so that the data that does actually get

1030
00:39:22,910 --> 00:39:20,880
recorded will look like it violates

1031
00:39:25,730 --> 00:39:22,920
velvet's inequality even though nothing

1032
00:39:27,890 --> 00:39:25,740
non-local has happened

1033
00:39:29,750 --> 00:39:27,900
um and then there was a question that

1034
00:39:33,410 --> 00:39:29,760
arose which is well how efficient can

1035
00:39:35,750 --> 00:39:33,420
you be that is you you want to say I can

1036
00:39:37,310 --> 00:39:35,760
rule out this kind of trick if my

1037
00:39:39,770 --> 00:39:37,320
detectors

1038
00:39:42,710 --> 00:39:39,780

are have a certain efficiency all right

1039
00:39:44,450 --> 00:39:42,720
if my detectors are 100 efficient if

1040
00:39:46,370 --> 00:39:44,460
every time I throw a particle at a

1041
00:39:48,410 --> 00:39:46,380
detector it registers

1042
00:39:50,030 --> 00:39:48,420
then I can't use this trick because the

1043
00:39:51,710 --> 00:39:50,040
trick really depends upon there being

1044
00:39:54,230 --> 00:39:51,720
these missing data

1045
00:39:56,690 --> 00:39:54,240
uh but then you say okay well how how

1046
00:40:00,050 --> 00:39:56,700
exactly how much

1047
00:40:02,210 --> 00:40:00,060
Efficiency do I need before I can rule

1048
00:40:04,630 --> 00:40:02,220
out this loophole

1049
00:40:07,609 --> 00:40:04,640
and to answer that I had to actually

1050
00:40:09,470 --> 00:40:07,619
solve a differential equation which I

1051
00:40:11,630 --> 00:40:09,480
offhand I didn't quite know how to solve

1052
00:40:12,410 --> 00:40:11,640
I could write it down

1053
00:40:14,630 --> 00:40:12,420
um

1054
00:40:16,970 --> 00:40:14,640
and I I was actually I was in Croatia

1055
00:40:20,030 --> 00:40:16,980
off the peach I had a big yellow legal

1056
00:40:23,810 --> 00:40:20,040
pad and I had a little hand calculator

1057
00:40:26,990 --> 00:40:23,820
and I swear to God I sat there and and

1058
00:40:30,650 --> 00:40:27,000
numerically simulated an integral by

1059
00:40:32,210 --> 00:40:30,660
hand with this calculator uh until I got

1060
00:40:33,849 --> 00:40:32,220
it close enough to say hey that looks

1061
00:40:36,710 --> 00:40:33,859
like pi over 4.

1062
00:40:38,270 --> 00:40:36,720
and then once I saw that I said oh yeah

1063
00:40:40,490 --> 00:40:38,280

it is pi over four then I could work out

1064
00:40:42,349 --> 00:40:40,500
right how it goes uh how long ago was

1065
00:40:44,630 --> 00:40:42,359
that oh that was

1066
00:40:48,530 --> 00:40:44,640
gosh 30 years ago okay so this is before

1067
00:40:51,770 --> 00:40:48,540
wolf from alpha oh yeah oh yeah this is

1068
00:40:54,470 --> 00:40:51,780
this is before you were born

1069
00:40:56,750 --> 00:40:54,480
okay oh yeah okay so just to be clear

1070
00:40:58,790 --> 00:40:56,760
efficiency because I haven't heard that

1071
00:41:01,130 --> 00:40:58,800
term efficiency Houston I'm not an

1072
00:41:02,690 --> 00:41:01,140
experimentalist yeah my the worst course

1073
00:41:04,550 --> 00:41:02,700
in physics for me was the experimental

1074
00:41:06,770 --> 00:41:04,560
part I'm much more of a mathematical

1075
00:41:08,690 --> 00:41:06,780
person well let me see let me give it an

1076
00:41:10,310 --> 00:41:08,700
example when we see the double slit

1077
00:41:12,650 --> 00:41:10,320
experiment you see these Dots Dots Dots

1078
00:41:14,750 --> 00:41:12,660
Dots Dots Dots well sometimes

1079
00:41:17,270 --> 00:41:14,760
you throw out a photon and it just

1080
00:41:19,010 --> 00:41:17,280
doesn't register right it a DOT doesn't

1081
00:41:20,930 --> 00:41:19,020
click yeah and then you think okay well

1082
00:41:23,030 --> 00:41:20,940
well if it's not going to click it's not

1083
00:41:25,010 --> 00:41:23,040
going to click in some uniform manner so

1084
00:41:28,250 --> 00:41:25,020
the pattern that I eventually get this

1085
00:41:29,870 --> 00:41:28,260
oscillating pattern it is characteristic

1086
00:41:32,270 --> 00:41:29,880
of the photon but you're saying there

1087
00:41:34,670 --> 00:41:32,280
are some ways of designing an experiment

1088
00:41:35,930 --> 00:41:34,680

such that the missing data gives you a

1089
00:41:39,829 --> 00:41:35,940
pattern that's actually not there

1090
00:41:41,450 --> 00:41:39,839
there's a there's a way if if so if

1091
00:41:43,190 --> 00:41:41,460
you're an experimentalist there's just a

1092
00:41:46,790 --> 00:41:43,200
straightforward question how efficient

1093
00:41:49,790 --> 00:41:46,800
are my detectors right I have a beam and

1094
00:41:51,349 --> 00:41:49,800
I know how many particles on average are

1095
00:41:52,970 --> 00:41:51,359
coming through this beam and then I know

1096
00:41:55,069 --> 00:41:52,980
how many particles on average are being

1097
00:41:56,630 --> 00:41:55,079
detected by my detectors and there's

1098
00:41:58,310 --> 00:41:56,640
going to be a gap right I mean stuff

1099
00:41:59,990 --> 00:41:58,320
gets lost

1100
00:42:02,390 --> 00:42:00,000
um nothing is nothing is a hundred

1101
00:42:06,470 --> 00:42:02,400
percent efficient

1102
00:42:08,750 --> 00:42:06,480
um in my book I describe a certain trick

1103
00:42:10,130 --> 00:42:08,760
it's a very conspiratorial trick it's

1104
00:42:11,930 --> 00:42:10,140
not anything that would be physically

1105
00:42:14,569 --> 00:42:11,940
natural I mean the whole thing is kind

1106
00:42:16,190 --> 00:42:14,579
of crazy but you're just doing logically

1107
00:42:18,770 --> 00:42:16,200
possible

1108
00:42:21,650 --> 00:42:18,780
um there's a trick you can use if

1109
00:42:23,810 --> 00:42:21,660
there's high enough inefficiency in the

1110
00:42:25,430 --> 00:42:23,820
detectors

1111
00:42:28,250 --> 00:42:25,440
so that

1112
00:42:30,790 --> 00:42:28,260
the registered data

1113
00:42:34,069 --> 00:42:30,800

would violate the Bell inequality

1114
00:42:37,190 --> 00:42:34,079
without anything non-local and the trick

1115
00:42:40,910 --> 00:42:37,200
involves a very judicious and special

1116
00:42:42,829 --> 00:42:40,920
use of cases where data disappears right

1117
00:42:44,650 --> 00:42:42,839
where no data shows up so it never gets

1118
00:42:48,410 --> 00:42:44,660
into the recorded data

1119
00:42:51,829 --> 00:42:50,089
you can do that I mean it's not

1120
00:42:54,410 --> 00:42:51,839
conceptually it's not really hard to see

1121
00:42:55,310 --> 00:42:54,420
how it works at all

1122
00:42:58,069 --> 00:42:55,320
um

1123
00:43:00,230 --> 00:42:58,079
uh it's just

1124
00:43:01,270 --> 00:43:00,240
there's a price to pay you're you're

1125
00:43:04,910 --> 00:43:01,280
you're you're

1126
00:43:07,550 --> 00:43:04,920
simulating by use of this trick

1127
00:43:10,069 --> 00:43:07,560
sending information where really no

1128
00:43:12,290 --> 00:43:10,079
information is being sent but you're

1129
00:43:13,730 --> 00:43:12,300
simulating it by use of this trick but

1130
00:43:15,650 --> 00:43:13,740
the more information you have to

1131
00:43:18,290 --> 00:43:15,660
simulate sending the more inefficient

1132
00:43:21,050 --> 00:43:18,300
the thing has to become

1133
00:43:23,990 --> 00:43:21,060
um you you have to more and more often

1134
00:43:25,670 --> 00:43:24,000
um uh use this trick of saying well uh

1135
00:43:27,589 --> 00:43:25,680
one of the particles is just going to

1136
00:43:30,530 --> 00:43:27,599
refuse to answer right I mean normally

1137
00:43:32,870 --> 00:43:30,540
you say I I take a particle and I send

1138
00:43:35,270 --> 00:43:32,880

it through a spin device and it's either

1139
00:43:36,829 --> 00:43:35,280
going to come out up or down but what if

1140
00:43:38,990 --> 00:43:36,839
the the particle has a third option

1141
00:43:40,970 --> 00:43:39,000
which is to just go mute and not give

1142
00:43:44,030 --> 00:43:40,980
you any answer at all and then get that

1143
00:43:46,190 --> 00:43:44,040
run gets deleted from the data

1144
00:43:48,530 --> 00:43:46,200
um it and so there's just a question of

1145
00:43:50,210 --> 00:43:48,540
how of what those numbers look like what

1146
00:43:51,849 --> 00:43:50,220
what is the

1147
00:43:54,530 --> 00:43:51,859
most

1148
00:43:57,290 --> 00:43:54,540
efficient way you can run that trick

1149
00:43:59,809 --> 00:43:57,300
because if you if your detectors then

1150
00:44:01,370 --> 00:43:59,819
have higher efficiency than that then

1151
00:44:03,770 --> 00:44:01,380
you can say well they can't be doing it

1152
00:44:05,870 --> 00:44:03,780
right you it's a loophole this there

1153
00:44:08,030 --> 00:44:05,880
were these kind of loopholes that people

1154
00:44:10,550 --> 00:44:08,040
talked about in tests of Bell's

1155
00:44:12,410 --> 00:44:10,560
inequality and the detector inefficiency

1156
00:44:14,270 --> 00:44:12,420
loophole was a big one for a long time

1157
00:44:16,190 --> 00:44:14,280
but they but you know generation after

1158
00:44:18,410 --> 00:44:16,200
generation of experimentalists just did

1159
00:44:19,970 --> 00:44:18,420
it better and better and better and got

1160
00:44:22,069 --> 00:44:19,980
higher and higher efficiencies and all

1161
00:44:24,770 --> 00:44:22,079
those loopholes have now been closed

1162
00:44:26,390 --> 00:44:24,780
okay experimentally closed sure sure

1163
00:44:27,650 --> 00:44:26,400

can't be the right answer

1164
00:44:29,870 --> 00:44:27,660
and you said that yours was

1165
00:44:31,990 --> 00:44:29,880
conspiratorial or do you mean contrived

1166
00:44:35,569 --> 00:44:32,000
the actual conditions

1167
00:44:37,550 --> 00:44:35,579
I mean it's it's like it's like the

1168
00:44:39,589 --> 00:44:37,560
electrons are out to trick us right I

1169
00:44:42,589 --> 00:44:39,599
mean it's a it the the the the the the

1170
00:44:45,530 --> 00:44:42,599
physical story

1171
00:44:47,510 --> 00:44:45,540
is not a natural one that anyone would

1172
00:44:49,670 --> 00:44:47,520
ever come up with you only come up with

1173
00:44:53,210 --> 00:44:49,680
it if you're sitting here saying I hate

1174
00:44:57,470 --> 00:44:53,220
non-locality I hate non-locality I want

1175
00:45:00,589 --> 00:44:57,480
some way to keep my physics local yet

1176
00:45:03,050 --> 00:45:00,599
consistent with the data that we have

1177
00:45:05,390 --> 00:45:03,060
and this is a trick which as long as the

1178
00:45:08,089 --> 00:45:05,400
data which you have there were certain

1179
00:45:09,890 --> 00:45:08,099
levels of detector and efficiencies it's

1180
00:45:11,630 --> 00:45:09,900
a trick you could use but there was

1181
00:45:13,730 --> 00:45:11,640
there's never a reason to believe it's

1182
00:45:16,190 --> 00:45:13,740
completely implausible physically

1183
00:45:18,230 --> 00:45:16,200
there's not no physical story behind it

1184
00:45:20,030 --> 00:45:18,240
it's just kind of looking well I could

1185
00:45:22,609 --> 00:45:20,040
you know this is possible this is

1186
00:45:24,950 --> 00:45:22,619
mathematically possible if I have enough

1187
00:45:27,530 --> 00:45:24,960
inefficiency to play with okay now let's

1188
00:45:30,650 --> 00:45:27,540

talk about quantum mechanics what I

1189
00:45:32,870 --> 00:45:30,660
noticed about you initially was I see

1190
00:45:35,809 --> 00:45:32,880
you as bringing some sober

1191
00:45:38,450 --> 00:45:35,819
reality to this whole realm of quantum

1192
00:45:40,849 --> 00:45:38,460
confusion and mysticism that generally

1193
00:45:43,370 --> 00:45:40,859
sells in magazines

1194
00:45:46,670 --> 00:45:43,380
spookiness strangeness other abnormal

1195
00:45:48,230 --> 00:45:46,680
qualities and then Bell's inequalities

1196
00:45:49,970 --> 00:45:48,240
generally sold as a trade-off between

1197
00:45:51,710 --> 00:45:49,980
non-locality and statistical

1198
00:45:55,370 --> 00:45:51,720
Independence or realism

1199
00:45:57,950 --> 00:45:55,380
so firstly is that the case and can you

1200
00:45:59,470 --> 00:45:57,960
tell the audience your view of what the

1201
00:46:04,730 --> 00:45:59,480
heck is going on Quantum mechanically

1202
00:46:06,530 --> 00:46:04,740
okay so uh all right yeah let me

1203
00:46:09,650 --> 00:46:06,540
let me start a little backwards here

1204
00:46:12,349 --> 00:46:09,660
this term realism has snuck into this

1205
00:46:13,970 --> 00:46:12,359
discussion and it really should just be

1206
00:46:14,569 --> 00:46:13,980
expunged

1207
00:46:18,050 --> 00:46:14,579
um

1208
00:46:20,450 --> 00:46:18,060
realism is not realism has nothing to do

1209
00:46:23,650 --> 00:46:20,460
with anything here in fact from a

1210
00:46:25,970 --> 00:46:23,660
philosophical point of view realism

1211
00:46:28,490 --> 00:46:25,980
scientific realism has to do with

1212
00:46:31,010 --> 00:46:28,500
epistemology doesn't have to do with

1213
00:46:33,109 --> 00:46:31,020

ontology with what there exists I mean

1214
00:46:34,609 --> 00:46:33,119
to say gosh

1215
00:46:37,430 --> 00:46:34,619
um

1216
00:46:39,890 --> 00:46:37,440
I can save I can save locality by just

1217
00:46:42,109 --> 00:46:39,900
giving up realism the way people say it

1218
00:46:44,089 --> 00:46:42,119
I often say oh yeah nothing actually

1219
00:46:46,370 --> 00:46:44,099
exists but thank God it's local I mean

1220
00:46:49,370 --> 00:46:46,380
it doesn't make any sense if you try and

1221
00:46:51,230 --> 00:46:49,380
Trace down people say oh Bell made some

1222
00:46:52,370 --> 00:46:51,240
Assumption of realism he made no such

1223
00:46:56,210 --> 00:46:52,380
assumption

1224
00:46:58,970 --> 00:46:56,220
made that you can just deny and then

1225
00:47:00,710 --> 00:46:58,980
you're okay all right the actual theorem

1226
00:47:03,470 --> 00:47:00,720
of bell which I think is the most

1227
00:47:04,910 --> 00:47:03,480
important and astonishing result I mean

1228
00:47:07,130 --> 00:47:04,920
there's the mathematical theorem and

1229
00:47:09,829 --> 00:47:07,140
then the fact in the lab that these

1230
00:47:11,450 --> 00:47:09,839
inequalities are violated this is the

1231
00:47:12,470 --> 00:47:11,460
most astonishing thing in the history of

1232
00:47:14,510 --> 00:47:12,480
physics

1233
00:47:17,630 --> 00:47:14,520
and the theorem

1234
00:47:20,210 --> 00:47:17,640
as a piece of mathematics this is just a

1235
00:47:22,550 --> 00:47:20,220
comment about it as mathematics

1236
00:47:24,910 --> 00:47:22,560
is the theory every theorem you're

1237
00:47:26,450 --> 00:47:24,920
deriving something from some

1238
00:47:31,010 --> 00:47:26,460

suppositions

1239
00:47:33,130 --> 00:47:31,020
that's called Bell locality it's the the

1240
00:47:35,690 --> 00:47:33,140
way that he expresses mathematically

1241
00:47:39,230 --> 00:47:35,700
what it would be if for a theory to be

1242
00:47:40,490 --> 00:47:39,240
local relativistically local meaning

1243
00:47:44,630 --> 00:47:40,500
that

1244
00:47:47,270 --> 00:47:44,640
faster than light

1245
00:47:49,490 --> 00:47:47,280
that all of the events

1246
00:47:52,790 --> 00:47:49,500
that can count as a cause of something

1247
00:47:56,750 --> 00:47:52,800
happening lie in or on its past light

1248
00:47:59,809 --> 00:47:56,760
cone right nothing that would require

1249
00:48:01,790 --> 00:47:59,819
going faster than light and and in

1250
00:48:03,890 --> 00:48:01,800
addition it will be relevant for where

1251
00:48:06,050 --> 00:48:03,900
this goes nothing coming from the future

1252
00:48:09,109 --> 00:48:06,060
either I mean Bell's locality condition

1253
00:48:10,970 --> 00:48:09,119
also rules out reverse causation that

1254
00:48:13,609 --> 00:48:10,980
the future could could somehow cause

1255
00:48:16,670 --> 00:48:13,619
things in the present

1256
00:48:18,770 --> 00:48:16,680
so there's the locality condition

1257
00:48:20,690 --> 00:48:18,780
and then as a mathematical fact there's

1258
00:48:22,430 --> 00:48:20,700
a second condition that he uses in the

1259
00:48:24,309 --> 00:48:22,440
derivation which is called statistical

1260
00:48:27,410 --> 00:48:24,319
Independence

1261
00:48:30,230 --> 00:48:27,420
and from these two assumptions he

1262
00:48:32,109 --> 00:48:30,240
derives an inequality and says okay if

1263
00:48:35,809 --> 00:48:32,119

if any Theory

1264
00:48:38,210 --> 00:48:35,819
satisfies locality and satisfies

1265
00:48:41,569 --> 00:48:38,220
statistical Independence

1266
00:48:43,730 --> 00:48:41,579
then there are certain constraints on

1267
00:48:45,710 --> 00:48:43,740
the sorts of correlations you could

1268
00:48:48,890 --> 00:48:45,720
possibly see

1269
00:48:52,849 --> 00:48:48,900
in situations where Alice and Bob

1270
00:48:55,309 --> 00:48:52,859
are in their Labs doing experiments

1271
00:48:57,170 --> 00:48:55,319
so far away from each other that light

1272
00:48:59,870 --> 00:48:57,180
doesn't have time

1273
00:49:02,809 --> 00:48:59,880
to get from one lab to the other so

1274
00:49:04,970 --> 00:49:02,819
there couldn't be any any effects if all

1275
00:49:06,050 --> 00:49:04,980
effects had to go at most at the speed

1276
00:49:08,210 --> 00:49:06,060
of light

1277
00:49:10,309 --> 00:49:08,220
there couldn't be any effects from what

1278
00:49:13,550 --> 00:49:10,319
happens in Alice's lab on what happens

1279
00:49:15,349 --> 00:49:13,560
in Bob's or vice versa okay

1280
00:49:17,270 --> 00:49:15,359
so that's the theorem

1281
00:49:18,890 --> 00:49:17,280
and then you go in and you see this this

1282
00:49:20,630 --> 00:49:18,900
inequality I mean first of all you

1283
00:49:22,910 --> 00:49:20,640
notice that quantum mechanics predicts

1284
00:49:24,230 --> 00:49:22,920
violations of this inequality and then

1285
00:49:26,450 --> 00:49:24,240
you notice that you go in the lab and

1286
00:49:30,230 --> 00:49:26,460
check and quantum mechanics quantum

1287
00:49:34,790 --> 00:49:32,630
um so you only had two suppositions from

1288
00:49:37,250 --> 00:49:34,800

which this follows locality and

1289
00:49:39,470 --> 00:49:37,260
statistical Independence so as a purely

1290
00:49:42,890 --> 00:49:39,480
logical matter you say well I have to at

1291
00:49:44,630 --> 00:49:42,900
least deny one or the other of these

1292
00:49:47,150 --> 00:49:44,640
um now

1293
00:49:49,670 --> 00:49:47,160
there are people who for reasons I do

1294
00:49:51,589 --> 00:49:49,680
not fathom I just literally don't

1295
00:49:56,510 --> 00:49:51,599
understand their reasons

1296
00:49:58,190 --> 00:49:56,520
are are so deeply committed to locality

1297
00:49:59,630 --> 00:49:58,200
that they're looking for any Escape

1298
00:50:01,490 --> 00:49:59,640
Route I mean that's more or less what we

1299
00:50:03,530 --> 00:50:01,500
were talking about with these with these

1300
00:50:05,329 --> 00:50:03,540
loopholes with these detection loopholes

1301
00:50:07,609 --> 00:50:05,339
right they don't like the idea of

1302
00:50:09,650 --> 00:50:07,619
non-locality and they're looking for any

1303
00:50:12,470 --> 00:50:09,660
Escape they can have

1304
00:50:14,329 --> 00:50:12,480
from from accepting it and these

1305
00:50:15,829 --> 00:50:14,339
detection loopholes for many years were

1306
00:50:18,109 --> 00:50:15,839
one until the experimentalists just

1307
00:50:20,089 --> 00:50:18,119
closed those loopholes they're gone

1308
00:50:21,230 --> 00:50:20,099
uh so the only other move pool is they

1309
00:50:23,089 --> 00:50:21,240
look at this and they say well I don't

1310
00:50:25,910 --> 00:50:23,099
want to deny locality I guess I have to

1311
00:50:27,950 --> 00:50:25,920
deny statistical Independence

1312
00:50:29,809 --> 00:50:27,960
and the problem with denying statistical

1313
00:50:32,329 --> 00:50:29,819

Independence is that it's kind of crazy

1314
00:50:35,450 --> 00:50:32,339
and it's it's crazy and conspiratorial

1315
00:50:37,910 --> 00:50:35,460
and on top of it you know as as you know

1316
00:50:39,050 --> 00:50:37,920
I've said and other people have said it

1317
00:50:42,410 --> 00:50:39,060
undermines

1318
00:50:45,010 --> 00:50:42,420
all scientific method I mean

1319
00:50:48,849 --> 00:50:45,020
if in order to get out of accepting

1320
00:50:51,410 --> 00:50:48,859
non-locality you deny

1321
00:50:54,470 --> 00:50:51,420
what's required assumptions that are

1322
00:50:56,870 --> 00:50:54,480
required to do science

1323
00:51:00,109 --> 00:50:56,880
that's not a good deal

1324
00:51:03,049 --> 00:51:00,119
right that's a really bad deal

1325
00:51:04,430 --> 00:51:03,059
speaking of that I sent you a video I'm

1326
00:51:07,130 --> 00:51:04,440
not sure if you had a chance to yeah

1327
00:51:08,630 --> 00:51:07,140
yeah I did okay so as a preface for

1328
00:51:10,490 --> 00:51:08,640
those who are watching the video is by

1329
00:51:13,069 --> 00:51:10,500
Sabine hostenfelder and it's on super

1330
00:51:15,470 --> 00:51:13,079
determinism either way I'll give a brief

1331
00:51:17,210 --> 00:51:15,480
description in the first 20 seconds or

1332
00:51:19,670 --> 00:51:17,220
so she says

1333
00:51:22,549 --> 00:51:19,680
some people think that if we do away

1334
00:51:25,069 --> 00:51:22,559
with statistical Independence then all

1335
00:51:26,990 --> 00:51:25,079
the science is undermined and she says

1336
00:51:29,210 --> 00:51:27,000
her attitude is no

1337
00:51:31,309 --> 00:51:29,220
so I'm curious to know your thoughts on

1338
00:51:33,710 --> 00:51:31,319

that firstly I am super determinism and

1339
00:51:35,930 --> 00:51:33,720
perhaps other specific comments were I

1340
00:51:37,730 --> 00:51:35,940
mean let me uh let me walk through this

1341
00:51:39,230 --> 00:51:37,740
although let me before because I knew

1342
00:51:41,569 --> 00:51:39,240
you were going to ask this let me just

1343
00:51:44,450 --> 00:51:41,579
point out to people because it's much

1344
00:51:46,549 --> 00:51:44,460
better than than listening to me if

1345
00:51:47,690 --> 00:51:46,559
you're interested in this be sure you

1346
00:51:49,430 --> 00:51:47,700
take

1347
00:51:52,430 --> 00:51:49,440
this book

1348
00:51:55,250 --> 00:51:52,440
John Bell's speakable and unspeakable in

1349
00:51:56,390 --> 00:51:55,260
quantum mechanics and very carefully

1350
00:51:58,490 --> 00:51:56,400
read

1351
00:52:01,069 --> 00:51:58,500
chapter 12

1352
00:52:02,870 --> 00:52:01,079
which is called free variables and local

1353
00:52:07,549 --> 00:52:02,880
causality

1354
00:52:09,710 --> 00:52:07,559
because Bell Nails it

1355
00:52:12,890 --> 00:52:09,720
completely

1356
00:52:14,329 --> 00:52:12,900
and any questions you have just he's

1357
00:52:16,210 --> 00:52:14,339
really

1358
00:52:19,010 --> 00:52:16,220
I mean Bell is an

1359
00:52:21,230 --> 00:52:19,020
extraordinarily precise

1360
00:52:23,510 --> 00:52:21,240
writer

1361
00:52:26,690 --> 00:52:23,520
he's not so good by the way if you watch

1362
00:52:28,430 --> 00:52:26,700
Sabina she talks about some interview he

1363
00:52:30,770 --> 00:52:28,440

gave and he's not so good in interviews

1364
00:52:32,630 --> 00:52:30,780
he sometimes slips up I would say

1365
00:52:34,849 --> 00:52:32,640
when he's talking off the top of his

1366
00:52:36,829 --> 00:52:34,859
head and says things which I think he

1367
00:52:38,569 --> 00:52:36,839
you know are just a bit sloppy and

1368
00:52:40,849 --> 00:52:38,579
uncharacteristic but when he writes

1369
00:52:43,069 --> 00:52:40,859
there are only a couple places it's an

1370
00:52:45,170 --> 00:52:43,079
entire book where I think he put a foot

1371
00:52:48,290 --> 00:52:45,180
wrong in what he writes well that's

1372
00:52:50,210 --> 00:52:48,300
everyone yeah I mean Comer nods I mean

1373
00:52:52,130 --> 00:52:50,220
everybody makes this case right we're

1374
00:52:55,130 --> 00:52:52,140
all making many more mistakes in real

1375
00:52:57,290 --> 00:52:55,140
time speech except everybody yeah and

1376
00:52:59,390 --> 00:52:57,300
and so if you're interested in this

1377
00:53:02,089 --> 00:52:59,400
topic and the the thing that amazes me

1378
00:53:05,089 --> 00:53:02,099
is I've had discussions with many people

1379
00:53:07,250 --> 00:53:05,099
who want to talk about super determinism

1380
00:53:09,470 --> 00:53:07,260
who've never read as far you know really

1381
00:53:11,450 --> 00:53:09,480
have never read this particular thing

1382
00:53:12,890 --> 00:53:11,460
which is the thing that Bell wrote about

1383
00:53:14,569 --> 00:53:12,900
it so three variables and local

1384
00:53:18,049 --> 00:53:14,579
causality and what I'm going to tell you

1385
00:53:21,290 --> 00:53:18,770
um

1386
00:53:22,730 --> 00:53:21,300
it has no and let's just start off by

1387
00:53:24,290 --> 00:53:22,740
saying this has nothing to do with free

1388
00:53:25,849 --> 00:53:24,300

will I mean all this talk about Free

1389
00:53:28,970 --> 00:53:25,859
Will has gotten into this discussion

1390
00:53:32,390 --> 00:53:28,980
from the beginning it was irrelevant

1391
00:53:34,849 --> 00:53:32,400
um the term super determinism is bad

1392
00:53:36,109 --> 00:53:34,859
because even as Sabina says you can't

1393
00:53:40,069 --> 00:53:36,119
get more deterministic than

1394
00:53:44,750 --> 00:53:40,790
um

1395
00:53:47,329 --> 00:53:44,760
the the issue is is the mathematical

1396
00:53:49,490 --> 00:53:47,339
Assumption of statistical Independence

1397
00:53:52,190 --> 00:53:49,500
that's used in the theorem

1398
00:53:53,990 --> 00:53:52,200
now what is that assumption let me just

1399
00:53:57,290 --> 00:53:54,000
give you an example and why it's

1400
00:53:59,390 --> 00:53:57,300
important and why I say If you deny it

1401
00:54:00,890 --> 00:53:59,400
empirical science kind of goes out the

1402
00:54:05,750 --> 00:54:00,900
window

1403
00:54:07,849 --> 00:54:05,760
so suppose we're going to do a a test

1404
00:54:09,410 --> 00:54:07,859
and there are different experimental

1405
00:54:12,829 --> 00:54:09,420
conditions you might think of them as

1406
00:54:15,770 --> 00:54:12,839
experimental in control or in in our

1407
00:54:18,109 --> 00:54:15,780
case you're going to either set up a a

1408
00:54:20,150 --> 00:54:18,119
spin measuring device in the X direction

1409
00:54:22,430 --> 00:54:20,160
or the y direction or in some other

1410
00:54:23,630 --> 00:54:22,440
direction we have these different

1411
00:54:26,450 --> 00:54:23,640
um conditions

1412
00:54:29,150 --> 00:54:26,460
and I'm doing tests and I'm doing tests

1413
00:54:31,089 --> 00:54:29,160

on a large number of items a large

1414
00:54:33,290 --> 00:54:31,099
number of rats or a large number of

1415
00:54:35,329 --> 00:54:33,300
particles or whatever

1416
00:54:37,450 --> 00:54:35,339
and I'm looking at statistics I'm

1417
00:54:40,670 --> 00:54:37,460
looking at at percentages

1418
00:54:42,410 --> 00:54:40,680
uh of the ones I experiment on with

1419
00:54:44,270 --> 00:54:42,420
these different conditions whether they

1420
00:54:46,670 --> 00:54:44,280
react this way or that way and when I'm

1421
00:54:50,510 --> 00:54:46,680
doing experiments on pairs on the

1422
00:54:51,950 --> 00:54:50,520
correlations between the two sides okay

1423
00:54:54,710 --> 00:54:51,960
now

1424
00:54:56,690 --> 00:54:54,720
what I do if I want to do just to take

1425
00:54:58,790 --> 00:54:56,700
the simple case everybody understands if

1426
00:55:01,309 --> 00:54:58,800
I want to check whether smoking causes

1427
00:55:04,250 --> 00:55:01,319
cancer in rats

1428
00:55:07,730 --> 00:55:04,260
I start out with a big group of rats

1429
00:55:10,370 --> 00:55:07,740
and then I want to subdivide it into an

1430
00:55:12,950 --> 00:55:10,380
experimental group in a control group

1431
00:55:16,250 --> 00:55:12,960
but I want to subdivide it in a way that

1432
00:55:17,990 --> 00:55:16,260
there's no bias between the two groups

1433
00:55:20,390 --> 00:55:18,000
the two groups

1434
00:55:23,210 --> 00:55:20,400
before I run the experiment are

1435
00:55:26,569 --> 00:55:23,220
statistically similar to each other

1436
00:55:28,609 --> 00:55:26,579
okay now there's some ways I can check

1437
00:55:30,349 --> 00:55:28,619
for that like if there are male rats and

1438
00:55:32,870 --> 00:55:30,359

female rats I can just kind of count

1439
00:55:34,130 --> 00:55:32,880
okay what percentage of Bale rats are in

1440
00:55:36,109 --> 00:55:34,140
this group and what percentage are in

1441
00:55:37,730 --> 00:55:36,119
this group and and I can make sure by

1442
00:55:40,670 --> 00:55:37,740
Distributing them that they have the

1443
00:55:42,530 --> 00:55:40,680
same percentages sure the thing is I

1444
00:55:44,270 --> 00:55:42,540
want the groups to be similar in all

1445
00:55:46,069 --> 00:55:44,280
respects even respects I'm completely

1446
00:55:48,290 --> 00:55:46,079
unaware of I mean maybe there's some

1447
00:55:51,010 --> 00:55:48,300
genes I don't know about

1448
00:55:54,710 --> 00:55:51,020
how do I do that well

1449
00:55:57,589 --> 00:55:54,720
I randomly assign

1450
00:55:59,930 --> 00:55:57,599
the rats to the two groups

1451
00:56:03,170 --> 00:55:59,940
this word random is important here the

1452
00:56:06,410 --> 00:56:03,180
word random here is absolutely important

1453
00:56:08,569 --> 00:56:06,420
what the word random there means it is

1454
00:56:11,030 --> 00:56:08,579
the condition that Bell uses of

1455
00:56:15,290 --> 00:56:11,040
statistical Independence it means that

1456
00:56:23,510 --> 00:56:18,710
does not is not biased or does not

1457
00:56:28,430 --> 00:56:23,520
respond or is not sensitive to the rats

1458
00:56:30,589 --> 00:56:28,440
okay so if I you you know you can

1459
00:56:32,690 --> 00:56:30,599
imagine flipping a coin for example I

1460
00:56:35,569 --> 00:56:32,700
mean that's a physical kind of what bell

1461
00:56:37,670 --> 00:56:35,579
would call a physical randomizer there's

1462
00:56:39,470 --> 00:56:37,680
there there are other randomizers I mean

1463
00:56:40,790 --> 00:56:39,480

he he uses this example which is very

1464
00:56:43,069 --> 00:56:40,800
nice because it takes all issues about

1465
00:56:44,870 --> 00:56:43,079
Free Will out of it he says look you

1466
00:56:47,870 --> 00:56:44,880
could use a pseudom a pseudo-random

1467
00:56:50,990 --> 00:56:47,880
number generator which works like this

1468
00:56:53,569 --> 00:56:51,000
start at the millionth digit of pi

1469
00:56:55,609 --> 00:56:53,579
and then output a one or a zero

1470
00:56:58,730 --> 00:56:55,619
depending upon whether the next digit is

1471
00:57:01,790 --> 00:56:58,740
even or odd all right so that'll give

1472
00:57:03,890 --> 00:57:01,800
you a sequence of ones and zeros that is

1473
00:57:05,870 --> 00:57:03,900
a pseudo-random sequence we call it

1474
00:57:08,270 --> 00:57:05,880
random because it will pass every

1475
00:57:09,589 --> 00:57:08,280
statistical test for Randomness you can

1476
00:57:11,270 --> 00:57:09,599
come up with

1477
00:57:14,329 --> 00:57:11,280
all right it'll be about the same number

1478
00:57:17,270 --> 00:57:14,339
of ones and zeros but there will be no

1479
00:57:19,069 --> 00:57:17,280
observable pattern

1480
00:57:20,750 --> 00:57:19,079
and you could use that and say okay for

1481
00:57:23,870 --> 00:57:20,760
one comes up then the rat goes this way

1482
00:57:28,130 --> 00:57:23,880
if a zero comes up it goes that way

1483
00:57:30,829 --> 00:57:28,140
now why do I do that because if the

1484
00:57:32,270 --> 00:57:30,839
Sorting is independent if whether the

1485
00:57:34,309 --> 00:57:32,280
rat went this way or that way is

1486
00:57:38,150 --> 00:57:34,319
independent of the of the nature of the

1487
00:57:40,490 --> 00:57:38,160
racks then with overwhelmingly high

1488
00:57:43,670 --> 00:57:40,500

probability that's calculable

1489
00:57:45,410 --> 00:57:43,680
each subgroup will be statistically like

1490
00:57:47,870 --> 00:57:45,420
the original group

1491
00:57:49,609 --> 00:57:47,880
if sixty percent of the rats had some

1492
00:57:53,329 --> 00:57:49,619
unknown feature in the original group

1493
00:57:55,609 --> 00:57:53,339
then 60 in each of the subgroups

1494
00:57:57,950 --> 00:57:55,619
will have that feature

1495
00:57:59,630 --> 00:57:57,960
and therefore the subgroups will be like

1496
00:58:01,970 --> 00:57:59,640
one another the really important thing

1497
00:58:05,870 --> 00:58:01,980
you want is you want the statistically

1498
00:58:07,609 --> 00:58:05,880
the subgroups to be like one another

1499
00:58:13,549 --> 00:58:07,619
and

1500
00:58:15,950 --> 00:58:13,559
for making these groups now if somebody

1501
00:58:18,770 --> 00:58:15,960
says now suppose I do this experiment

1502
00:58:21,170 --> 00:58:18,780
with the rats I take this big group I

1503
00:58:22,910 --> 00:58:21,180
randomly divide them by one of these

1504
00:58:25,849 --> 00:58:22,920
sorting mechanisms right by throwing

1505
00:58:28,250 --> 00:58:25,859
dice or by this sure randomizer whatever

1506
00:58:30,950 --> 00:58:28,260
into these two groups and then I expose

1507
00:58:32,690 --> 00:58:30,960
one to smoke and I treat the other the

1508
00:58:34,910 --> 00:58:32,700
same except I don't expose it to smoke

1509
00:58:37,309 --> 00:58:34,920
and then I see a lot more cancer in this

1510
00:58:38,930 --> 00:58:37,319
group then we infer that the smoke

1511
00:58:41,870 --> 00:58:38,940
caused cancer

1512
00:58:44,390 --> 00:58:41,880
now if somebody says no no no no really

1513
00:58:47,150 --> 00:58:44,400

what's going on is this some of the rats

1514
00:58:48,410 --> 00:58:47,160
were predisposed to get cancer no matter

1515
00:58:51,230 --> 00:58:48,420
what

1516
00:58:53,030 --> 00:58:51,240
and other the rats weren't and it just

1517
00:58:54,890 --> 00:58:53,040
turned out that the ones that were

1518
00:58:56,690 --> 00:58:54,900
predisposed got sorted over into the

1519
00:58:58,130 --> 00:58:56,700
ones into the smoke group and the ones

1520
00:59:00,170 --> 00:58:58,140
that weren't got sorted over into the

1521
00:59:01,609 --> 00:59:00,180
other group and so the smoking had

1522
00:59:03,770 --> 00:59:01,619
nothing to do with it now this is the

1523
00:59:06,349 --> 00:59:03,780
kind of argument that actual lawyers for

1524
00:59:07,849 --> 00:59:06,359
the tobacco industry used to make when

1525
00:59:10,130 --> 00:59:07,859
they were trying to argue that

1526
00:59:13,309 --> 00:59:10,140
scientists had not that smoking causes

1527
00:59:17,030 --> 00:59:13,319
cancer and and obviously as a purely

1528
00:59:19,490 --> 00:59:17,040
logical fact yes if

1529
00:59:22,190 --> 00:59:19,500
if the Sorting didn't work

1530
00:59:24,890 --> 00:59:22,200
to make statistically similar subgroups

1531
00:59:26,150 --> 00:59:24,900
then that could be an explanation but

1532
00:59:29,030 --> 00:59:26,160
then you have to go on and say I don't

1533
00:59:32,569 --> 00:59:29,040
care how you sort sort any way you want

1534
00:59:35,690 --> 00:59:32,579
right sort based on on Pi sort based on

1535
00:59:38,569 --> 00:59:35,700
uh the number of shares of stocks sold

1536
00:59:40,490 --> 00:59:38,579
on the shot Stock Exchange sort based on

1537
00:59:42,069 --> 00:59:40,500
anything you want no matter how you do

1538
00:59:44,630 --> 00:59:42,079

it somehow

1539
00:59:46,910 --> 00:59:44,640
the cancer-prone rats are going to go

1540
00:59:49,609 --> 00:59:46,920
this way and the non-cancer rats are

1541
00:59:52,069 --> 00:59:49,619
going to go that way now that will as it

1542
00:59:54,349 --> 00:59:52,079
were as a purely logical matter count as

1543
00:59:56,089 --> 00:59:54,359
a as something that would make the

1544
00:59:58,069 --> 00:59:56,099
prediction that this group will get more

1545
01:00:00,230 --> 00:59:58,079
cancer than that group but we would just

1546
01:00:02,030 --> 01:00:00,240
say this is lunacy

1547
01:00:04,309 --> 01:00:02,040
because you have no mechanism there's

1548
01:00:07,190 --> 01:00:04,319
nothing you know you're just you just

1549
01:00:08,750 --> 01:00:07,200
don't like the result okay you don't

1550
01:00:10,730 --> 01:00:08,760
like the result and you don't like what

1551
01:00:13,010 --> 01:00:10,740
the result is telling you so you're just

1552
01:00:14,630 --> 01:00:13,020
grasping at straws that's all that's

1553
01:00:17,089 --> 01:00:14,640
going on here

1554
01:00:19,910 --> 01:00:17,099
that's what's super somebody who just

1555
01:00:22,250 --> 01:00:19,920
says I'm just gonna blankly deny

1556
01:00:23,930 --> 01:00:22,260
statistical Independence no matter how

1557
01:00:26,390 --> 01:00:23,940
you do this sorting no matter and in

1558
01:00:28,609 --> 01:00:26,400
this case you're doing these experiments

1559
01:00:30,829 --> 01:00:28,619
Alice is doing an experiment and Bob's

1560
01:00:33,470 --> 01:00:30,839
doing an experiment each one is randomly

1561
01:00:35,329 --> 01:00:33,480
choosing how to set their device

1562
01:00:37,609 --> 01:00:35,339
and it's there where the randomness

1563
01:00:39,049 --> 01:00:37,619

comes in how does the device get set and

1564
01:00:40,730 --> 01:00:39,059
they could be flipping coins or they

1565
01:00:42,650 --> 01:00:40,740
could be running off pie or with doing

1566
01:00:46,150 --> 01:00:42,660
whatever the heck they want

1567
01:00:49,970 --> 01:00:46,160
and your the bell's only assumption is

1568
01:00:52,190 --> 01:00:49,980
that statistically

1569
01:00:54,049 --> 01:00:52,200
the group of particles that meet

1570
01:00:56,390 --> 01:00:54,059
condition one

1571
01:00:58,910 --> 01:00:56,400
will be the same as the group of

1572
01:01:00,770 --> 01:00:58,920
particles that meet condition two

1573
01:01:03,289 --> 01:01:00,780
where condition one and condition two

1574
01:01:05,450 --> 01:01:03,299
are chosen by one of these pseudo-random

1575
01:01:07,849 --> 01:01:05,460
kind of processes

1576
01:01:11,329 --> 01:01:07,859
now Bell gives a even more extensive

1577
01:01:13,309 --> 01:01:11,339
discussion of why this is true but it's

1578
01:01:15,130 --> 01:01:13,319
clear that when we say it would

1579
01:01:19,250 --> 01:01:15,140
undermine science

1580
01:01:22,730 --> 01:01:19,260
experimental method depends upon in all

1581
01:01:24,950 --> 01:01:22,740
cases using this yeah I should say one

1582
01:01:27,589 --> 01:01:24,960
more thing

1583
01:01:30,829 --> 01:01:27,599
there's another idea

1584
01:01:33,170 --> 01:01:30,839
which is retro causation

1585
01:01:36,109 --> 01:01:33,180
right which is a different idea it's not

1586
01:01:38,630 --> 01:01:36,119
just a blank denial of statistical

1587
01:01:42,309 --> 01:01:38,640
Independence it says oh statistical

1588
01:01:45,890 --> 01:01:42,319

Independence fails because

1589
01:01:48,170 --> 01:01:45,900
the nature of the particles when I made

1590
01:01:51,109 --> 01:01:48,180
them right

1591
01:01:53,990 --> 01:01:51,119
is somehow affected by

1592
01:01:56,510 --> 01:01:54,000
at the time I made them okay is somehow

1593
01:02:00,829 --> 01:01:56,520
affected by what experimental condition

1594
01:02:06,049 --> 01:02:03,370
so that's the future

1595
01:02:08,809 --> 01:02:06,059
affecting the past that's retro

1596
01:02:13,670 --> 01:02:11,030
okay and all of this is to save locality

1597
01:02:15,170 --> 01:02:13,680
well that doesn't say vocality so the

1598
01:02:17,030 --> 01:02:15,180
first point I want to make is that retro

1599
01:02:18,410 --> 01:02:17,040
causation violates Bell's locality

1600
01:02:21,410 --> 01:02:18,420
condition

1601
01:02:23,690 --> 01:02:21,420
okay and it would be kind of crazy to

1602
01:02:25,010 --> 01:02:23,700
think look I I have Bob and Alice and

1603
01:02:27,650 --> 01:02:25,020
they're doing their experiments far

1604
01:02:29,870 --> 01:02:27,660
apart and I absolutely will not believe

1605
01:02:32,329 --> 01:02:29,880
that what Alice does can have a causal

1606
01:02:34,910 --> 01:02:32,339
effect on Bob but I believe that stuff

1607
01:02:36,650 --> 01:02:34,920
that happens to the Future can have a

1608
01:02:38,390 --> 01:02:36,660
causal effect on Bob I mean that's

1609
01:02:40,370 --> 01:02:38,400
that's even worse

1610
01:02:42,109 --> 01:02:40,380
and it's even worse because if you have

1611
01:02:43,730 --> 01:02:42,119
retro causation then because you have

1612
01:02:46,069 --> 01:02:43,740
causation from the you certainly have

1613
01:02:47,450 --> 01:02:46,079

causation from the past to the future if

1614
01:02:49,130 --> 01:02:47,460
you also have causation from the future

1615
01:02:51,890 --> 01:02:49,140
to the Past then you're going to be

1616
01:02:53,750 --> 01:02:51,900
involved in causal loops and then they

1617
01:02:56,690 --> 01:02:53,760
it's very hard to even write down a

1618
01:02:58,130 --> 01:02:56,700
coherent Theory I mean wheeler and

1619
01:02:59,569 --> 01:02:58,140
Feynman tried to do it it's not clear

1620
01:03:01,609 --> 01:02:59,579
they wrote down some equations it's not

1621
01:03:04,789 --> 01:03:01,619
clear if they have any solutions

1622
01:03:07,609 --> 01:03:04,799
if you if you just have non-locality

1623
01:03:09,349 --> 01:03:07,619
you you it doesn't they're they're the

1624
01:03:11,030 --> 01:03:09,359
the obvious ways to implement it will

1625
01:03:13,970 --> 01:03:11,040
not involve any causal groups you won't

1626
01:03:17,390 --> 01:03:13,980
have that problem but the fact is to say

1627
01:03:19,130 --> 01:03:17,400
I I want to deny non-locality and

1628
01:03:21,710 --> 01:03:19,140
therefore Embrace retro causation well

1629
01:03:23,569 --> 01:03:21,720
first of all it retro causation violates

1630
01:03:25,370 --> 01:03:23,579
Bell's locality conditions so you

1631
01:03:26,870 --> 01:03:25,380
haven't gotten out of it anyway and

1632
01:03:27,890 --> 01:03:26,880
you've gotten yourself even to a worse

1633
01:03:29,569 --> 01:03:27,900
problem

1634
01:03:31,970 --> 01:03:29,579
forgive me because I'm uncertain here

1635
01:03:34,190 --> 01:03:31,980
and I'll just fumble over my words and

1636
01:03:36,650 --> 01:03:34,200
then you can perhaps co-hear what I'm

1637
01:03:38,630 --> 01:03:36,660
saying and say it better than I have

1638
01:03:40,370 --> 01:03:38,640

how far does this correlation have to be

1639
01:03:41,990 --> 01:03:40,380
so when I hear statistical Independence

1640
01:03:44,569 --> 01:03:42,000
opposite of statistical dependence which

1641
01:03:46,970 --> 01:03:44,579
I assume is a correlation and it seems

1642
01:03:49,010 --> 01:03:46,980
to me clear that even when we sort rats

1643
01:03:50,630 --> 01:03:49,020
if we try to do so randomly by picking

1644
01:03:52,549 --> 01:03:50,640
the 1 millionth digit of pi and so on

1645
01:03:55,130 --> 01:03:52,559
and going forward from there that there

1646
01:03:57,530 --> 01:03:55,140
is still some some dependence it's

1647
01:03:59,210 --> 01:03:57,540
extremely extremely small now how well

1648
01:04:01,430 --> 01:03:59,220
how do we choose the number one million

1649
01:04:02,870 --> 01:04:01,440
well okay this person said okay well

1650
01:04:05,030 --> 01:04:02,880
let's choose a random number generator

1651
01:04:07,190 --> 01:04:05,040
to choose that one million or to choose

1652
01:04:10,549 --> 01:04:07,200
some number of the digits of pi okay

1653
01:04:12,109 --> 01:04:10,559
well then when we press on the random

1654
01:04:13,789 --> 01:04:12,119
number generator why do we choose to

1655
01:04:15,109 --> 01:04:13,799
press it five seconds from now versus 10

1656
01:04:17,089 --> 01:04:15,119
seconds from now because it would give

1657
01:04:19,849 --> 01:04:17,099
you a different number so essentially

1658
01:04:22,609 --> 01:04:19,859
what I'm saying is that the world that

1659
01:04:24,890 --> 01:04:22,619
we chose the rats from

1660
01:04:26,210 --> 01:04:24,900
every single thing here is influencing

1661
01:04:28,309 --> 01:04:26,220
our decision

1662
01:04:29,750 --> 01:04:28,319
so every single thing is in the so the

1663
01:04:32,270 --> 01:04:29,760

rat's temperature is influencing our

1664
01:04:33,589 --> 01:04:32,280
decision the the fact that the rats have

1665
01:04:35,329 --> 01:04:33,599
a certain amount of hair is influences

1666
01:04:37,849 --> 01:04:35,339
our decision and so on so just just

1667
01:04:41,770 --> 01:04:37,859
there's a there's an extremely tiny

1668
01:04:47,450 --> 01:04:45,049
0.0002 but I don't know is that the fact

1669
01:04:48,710 --> 01:04:47,460
that it's non-zero does that have any

1670
01:04:51,410 --> 01:04:48,720
implication or does it need to be

1671
01:04:55,309 --> 01:04:51,420
non-zero sufficiently large

1672
01:04:58,370 --> 01:04:55,319
okay so so let me let me try and address

1673
01:05:00,890 --> 01:04:58,380
there are two parts of this I think uh

1674
01:05:02,930 --> 01:05:00,900
let me try and address both parts of it

1675
01:05:04,849 --> 01:05:02,940
let me just take my simple case so

1676
01:05:07,970 --> 01:05:04,859
everybody can follow I have a big group

1677
01:05:09,770 --> 01:05:07,980
of rats and some percentage of them say

1678
01:05:11,329 --> 01:05:09,780
have a certain Gene I don't even know

1679
01:05:15,230 --> 01:05:11,339
about the gene

1680
01:05:18,410 --> 01:05:15,240
but you say 60 in the big group have it

1681
01:05:21,170 --> 01:05:18,420
and what I want to do is now partition

1682
01:05:23,030 --> 01:05:21,180
this into two groups of rats and I want

1683
01:05:24,650 --> 01:05:23,040
the two groups to be statistically like

1684
01:05:26,390 --> 01:05:24,660
each other and therefore statistically

1685
01:05:27,349 --> 01:05:26,400
like the original group which had 60

1686
01:05:30,410 --> 01:05:27,359
percent

1687
01:05:33,410 --> 01:05:30,420
now if I just flip a coin

1688
01:05:35,510 --> 01:05:33,420

it just standard statistics

1689
01:05:37,309 --> 01:05:35,520
will tell you all right there'll be

1690
01:05:40,010 --> 01:05:37,319
little fluctuates it doesn't mean that

1691
01:05:42,530 --> 01:05:40,020
you'll get exactly 60 in each of your

1692
01:05:45,589 --> 01:05:42,540
subgroups right one subgroup might end

1693
01:05:49,670 --> 01:05:45,599
up with 61 in the other subgroup with 59

1694
01:05:51,950 --> 01:05:49,680
those are just statistical fluctuations

1695
01:05:53,630 --> 01:05:51,960
um using standard statistical methods

1696
01:05:56,030 --> 01:05:53,640
you calculate the likelihood of these

1697
01:05:59,870 --> 01:05:56,040
fluctuations if you're worried about

1698
01:06:02,089 --> 01:05:59,880
them then you you make a bigger you use

1699
01:06:04,309 --> 01:06:02,099
a bigger group okay sure it makes the

1700
01:06:06,829 --> 01:06:04,319
fluctuations the probability of the

1701
01:06:09,049 --> 01:06:06,839
fluctuation smaller and smaller

1702
01:06:10,910 --> 01:06:09,059
um without limit right you can't drive

1703
01:06:13,970 --> 01:06:10,920
it to zero but you can drive them below

1704
01:06:15,530 --> 01:06:13,980
any epsilonic right right

1705
01:06:17,930 --> 01:06:15,540
just to be clear what I'm wondering is

1706
01:06:21,190 --> 01:06:17,940
is the presence of any Epsilon does that

1707
01:06:24,049 --> 01:06:21,200
undermine the no no because because

1708
01:06:26,809 --> 01:06:24,059
the violations of bells and Bell's

1709
01:06:29,870 --> 01:06:26,819
inequality says a certain observed

1710
01:06:32,630 --> 01:06:29,880
correlation in the lab cannot be greater

1711
01:06:35,630 --> 01:06:32,640
than a given number I see I see I mean

1712
01:06:36,470 --> 01:06:35,640
actual observed violation of that is so

1713
01:06:40,010 --> 01:06:36,480

far

1714
01:06:42,829 --> 01:06:40,020
it's not close right it's not like gosh

1715
01:06:45,470 --> 01:06:42,839
it's just a tiny bit over and if I just

1716
01:06:48,890 --> 01:06:45,480
have a little epsilonic thing somewhere

1717
01:06:50,510 --> 01:06:48,900
no no the violation is radically far

1718
01:06:53,569 --> 01:06:50,520
away from the limit

1719
01:06:54,950 --> 01:06:53,579
so if you say oh maybe the subgroups

1720
01:06:58,309 --> 01:06:54,960
aren't exactly the same of course

1721
01:07:00,230 --> 01:06:58,319
they're not exactly the same but the

1722
01:07:01,490 --> 01:07:00,240
chances of them being sufficiently

1723
01:07:04,190 --> 01:07:01,500
different

1724
01:07:05,809 --> 01:07:04,200
to account for what's observed and

1725
01:07:07,549 --> 01:07:05,819
furthermore of course what's observed is

1726
01:07:09,410 --> 01:07:07,559
exactly what's predicted by quantum

1727
01:07:10,910 --> 01:07:09,420
mechanics and if if what you were seeing

1728
01:07:12,349 --> 01:07:10,920
was just the result of some random

1729
01:07:13,670 --> 01:07:12,359
fluctuation then you wouldn't be able to

1730
01:07:15,410 --> 01:07:13,680
predict it I mean that's the point about

1731
01:07:17,990 --> 01:07:15,420
random fluctuations is you can't predict

1732
01:07:20,329 --> 01:07:18,000
them at all but what You observe in the

1733
01:07:22,510 --> 01:07:20,339
lab is precisely when you get out of a

1734
01:07:25,370 --> 01:07:22,520
quantum mechanical calculation

1735
01:07:30,109 --> 01:07:25,380
yeah there's one other thing I just want

1736
01:07:33,289 --> 01:07:31,910
this thing of bells because it's

1737
01:07:41,390 --> 01:07:33,299
relevant to what you said well we could

1738
01:07:45,770 --> 01:07:43,549

actually here's a relevant a relevant

1739
01:07:50,150 --> 01:07:45,780
thing to what you just said

1740
01:07:57,710 --> 01:07:53,990
he's talking about you've got some

1741
01:08:01,069 --> 01:07:57,720
things you treat as free variables in

1742
01:08:04,190 --> 01:08:01,079
this case the choice of whether to do

1743
01:08:06,230 --> 01:08:04,200
experiment a or experiment B the choice

1744
01:08:09,230 --> 01:08:06,240
of Allison bobnick he says of course

1745
01:08:10,130 --> 01:08:09,240
there's an Infinite infamous ambiguity

1746
01:08:13,849 --> 01:08:10,140
here

1747
01:08:16,370 --> 01:08:13,859
elements are

1748
01:08:19,070 --> 01:08:16,380
the fields of stern Garlock magnets

1749
01:08:21,169 --> 01:08:19,080
could be treated as external that's then

1750
01:08:23,930 --> 01:08:21,179
treating those as free variables so I

1751
01:08:26,269 --> 01:08:23,940
can just you know I imagine those I set

1752
01:08:28,249 --> 01:08:26,279
them when I do the calculation however I

1753
01:08:29,749 --> 01:08:28,259
want or fields and magnets could be

1754
01:08:31,669 --> 01:08:29,759
included in the quantum mechanical

1755
01:08:34,070 --> 01:08:31,679
system with external agents acting only

1756
01:08:35,990 --> 01:08:34,080
on external knobs and switches or the

1757
01:08:38,150 --> 01:08:36,000
external agents could be located in the

1758
01:08:39,829 --> 01:08:38,160
brain of the experimental in the latter

1759
01:08:41,570 --> 01:08:39,839
case the setting of the instrument is

1760
01:08:44,150 --> 01:08:41,580
not itself a free variable it's only

1761
01:08:45,709 --> 01:08:44,160
more or less closely correlated with one

1762
01:08:48,169 --> 01:08:45,719
depending on how accurately the

1763
01:08:49,970 --> 01:08:48,179

experimenter affects his intention as he

1764
01:08:52,070 --> 01:08:49,980
puts out his hand to the knob his hand

1765
01:08:54,530 --> 01:08:52,080
May shake and may Shake in a way

1766
01:08:57,110 --> 01:08:54,540
influenced by the variables V remember

1767
01:08:58,610 --> 01:08:57,120
right now this is now exactly to your

1768
01:09:01,910 --> 01:08:58,620
point this is Belle I'm reading right

1769
01:09:04,430 --> 01:09:01,920
okay that the disagreement between

1770
01:09:06,890 --> 01:09:04,440
locality and quantum mechanics is large

1771
01:09:09,769 --> 01:09:06,900
up to a factor of root 2 in certain

1772
01:09:11,570 --> 01:09:09,779
sense so some hand trembling can be

1773
01:09:12,610 --> 01:09:11,580
tolerated without much change in the

1774
01:09:14,450 --> 01:09:12,620
conclusion

1775
01:09:19,309 --> 01:09:14,460
quantification of this would require

1776
01:09:22,490 --> 01:09:19,319
careful epsilonis okay and I I mean

1777
01:09:24,229 --> 01:09:22,500
there's a another

1778
01:09:25,669 --> 01:09:24,239
thing that he talks about it which I

1779
01:09:30,289 --> 01:09:25,679
just

1780
01:09:31,490 --> 01:09:30,299
end he's talking about this is the part

1781
01:09:33,410 --> 01:09:31,500
that I wanted

1782
01:09:34,970 --> 01:09:33,420
consider the extreme case he's now

1783
01:09:36,709 --> 01:09:34,980
talking about random generators so we

1784
01:09:38,390 --> 01:09:36,719
want something that's setting this

1785
01:09:40,370 --> 01:09:38,400
equipment either this way or that way

1786
01:09:43,249 --> 01:09:40,380
for Alice something that's setting it

1787
01:09:45,229 --> 01:09:43,259
this way or that way for Bob

1788
01:09:47,390 --> 01:09:45,239

um it would be a bad idea to have it due

1789
01:09:48,950 --> 01:09:47,400
to the as it were whim of the

1790
01:09:51,289 --> 01:09:48,960
experimenter because the experimenter

1791
01:09:54,110 --> 01:09:51,299
would have to be just sitting there in a

1792
01:09:55,910 --> 01:09:54,120
very boring way going oh now up now down

1793
01:09:57,709 --> 01:09:55,920
and probably as we know people are not

1794
01:09:59,990 --> 01:09:57,719
even good at creating random sequences

1795
01:10:01,970 --> 01:10:00,000
right human beings are not good random

1796
01:10:03,169 --> 01:10:01,980
number generators right right here's

1797
01:10:05,570 --> 01:10:03,179
what he said he says consider the

1798
01:10:07,850 --> 01:10:05,580
extreme case of a random generator

1799
01:10:09,290 --> 01:10:07,860
which is in fact perfectly deterministic

1800
01:10:13,130 --> 01:10:09,300
in nature

1801
01:10:15,410 --> 01:10:13,140
and for Simplicity perfectly isolated in

1802
01:10:18,650 --> 01:10:15,420
such a device the complete final state

1803
01:10:20,990 --> 01:10:18,660
right what what it chooses

1804
01:10:23,750 --> 01:10:21,000
perfectly determines the complete

1805
01:10:26,750 --> 01:10:23,760
initial State nothing is forgotten

1806
01:10:29,390 --> 01:10:26,760
and yet for many purposes such a device

1807
01:10:31,910 --> 01:10:29,400
is precisely a forgetting machine

1808
01:10:34,610 --> 01:10:31,920
a particular output is the result of

1809
01:10:36,890 --> 01:10:34,620
combining so many factors of such

1810
01:10:38,450 --> 01:10:36,900
lengthy and complicated dynamical chain

1811
01:10:40,189 --> 01:10:38,460
and this is going what you were saying

1812
01:10:42,290 --> 01:10:40,199
well what if they do it a little later

1813
01:10:43,970 --> 01:10:42,300

or if I've have you know suppose I have

1814
01:10:45,590 --> 01:10:43,980
like when they do lotteries they have

1815
01:10:47,810 --> 01:10:45,600
these ping pong balls that are bouncing

1816
01:10:49,970 --> 01:10:47,820
up and down in this cage okay that could

1817
01:10:51,470 --> 01:10:49,980
be a deterministic system so that some

1818
01:10:54,770 --> 01:10:51,480
set of causes

1819
01:10:57,169 --> 01:10:54,780
account for why this ball came up but

1820
01:10:58,550 --> 01:10:57,179
that set of causes is huge it involves

1821
01:10:59,750 --> 01:10:58,560
all the other collisions with all the

1822
01:11:01,669 --> 01:10:59,760
other balls and all this other stuff

1823
01:11:03,530 --> 01:11:01,679
going on so he says

1824
01:11:06,229 --> 01:11:03,540
um yet for many purposes such a device

1825
01:11:08,750 --> 01:11:06,239
is precisely a forgetting machine a

1826
01:11:11,330 --> 01:11:08,760
particular output is the result of

1827
01:11:14,209 --> 01:11:11,340
combining so many factors of such

1828
01:11:16,010 --> 01:11:14,219
lengthy and complicated dynamical chain

1829
01:11:18,530 --> 01:11:16,020
that it is quite extraordinarily

1830
01:11:21,709 --> 01:11:18,540
sensitive to minute variations of any

1831
01:11:23,270 --> 01:11:21,719
one of many initial conditions it is the

1832
01:11:25,910 --> 01:11:23,280
familiar Paradox of classical

1833
01:11:28,130 --> 01:11:25,920
statistical mechanics that such

1834
01:11:30,830 --> 01:11:28,140
Exquisite sensitivity to initial

1835
01:11:33,169 --> 01:11:30,840
conditions is practically equivalent to

1836
01:11:35,330 --> 01:11:33,179
complete forgetfulness of them

1837
01:11:37,189 --> 01:11:35,340
to illustrate this point suppose that

1838
01:11:38,990 --> 01:11:37,199

the choice between two possible outputs

1839
01:11:40,970 --> 01:11:39,000
corresponding to a and a prime depending

1840
01:11:42,950 --> 01:11:40,980
on the oddness or evenness of the digit

1841
01:11:45,770 --> 01:11:42,960
in the millionth decimal place of some

1842
01:11:47,950 --> 01:11:45,780
input variable then fixing a or a prime

1843
01:11:50,450 --> 01:11:47,960
indeed fixes something about the input

1844
01:11:52,910 --> 01:11:50,460
I.E whether the millionth digit is even

1845
01:11:54,950 --> 01:11:52,920
or odd but this peculiar piece of

1846
01:11:56,990 --> 01:11:54,960
information is unlikely to be the vital

1847
01:11:59,750 --> 01:11:57,000
piece for any other distinctively

1848
01:12:02,750 --> 01:11:59,760
different purpose I.E it is otherwise

1849
01:12:04,370 --> 01:12:02,760
rather useless with a physical shuffling

1850
01:12:06,110 --> 01:12:04,380
machine we're unable to perform the

1851
01:12:08,149 --> 01:12:06,120
analysis to the point of saying just

1852
01:12:10,070 --> 01:12:08,159
what particular feature of the input is

1853
01:12:12,290 --> 01:12:10,080
Remembered in the output but we can

1854
01:12:15,410 --> 01:12:12,300
quite reasonably assume that it is not

1855
01:12:17,930 --> 01:12:15,420
relevant for other purposes in this

1856
01:12:21,410 --> 01:12:17,940
sense the device output of such a device

1857
01:12:23,689 --> 01:12:21,420
is indeed a sufficiently free variable

1858
01:12:26,390 --> 01:12:23,699
for the purposes at hand

1859
01:12:28,370 --> 01:12:26,400
for this purpose the Assumption one

1860
01:12:30,110 --> 01:12:28,380
which is the statistical Independence

1861
01:12:32,630 --> 01:12:30,120
assumption in the proof

1862
01:12:35,030 --> 01:12:32,640
is then true enough and the theorem

1863
01:12:37,669 --> 01:12:35,040

follows now if you just understand if

1864
01:12:39,470 --> 01:12:37,679
you just read that paragraph carefully

1865
01:12:41,630 --> 01:12:39,480
and understand it

1866
01:12:44,990 --> 01:12:41,640
it puts this whole thing about I'm going

1867
01:12:47,570 --> 01:12:45,000
to deny statistical Independence to bed

1868
01:12:49,610 --> 01:12:47,580
I mean and this is just Bell okay he

1869
01:12:52,370 --> 01:12:49,620
understood this objection he understood

1870
01:12:55,130 --> 01:12:52,380
that logically yes he has two premises

1871
01:12:56,630 --> 01:12:55,140
so logically you can deny either one but

1872
01:12:59,290 --> 01:12:56,640
then he says look denying statistical

1873
01:13:01,970 --> 01:12:59,300
Independence that's just not

1874
01:13:05,030 --> 01:13:01,980
physically the kind of thing a physicist

1875
01:13:07,550 --> 01:13:05,040
could ever do and remain a physicist

1876
01:13:09,770 --> 01:13:07,560
here's what's interesting I respect you

1877
01:13:11,750 --> 01:13:09,780
I respect Sabine I think you're both

1878
01:13:14,030 --> 01:13:11,760
extremely bright people

1879
01:13:16,189 --> 01:13:14,040
why is it then that extremely bright

1880
01:13:18,830 --> 01:13:16,199
respectable people believe in super

1881
01:13:21,050 --> 01:13:18,840
determinism if it's so obviously

1882
01:13:23,270 --> 01:13:21,060
incorrect so here's one answer Nima

1883
01:13:25,910 --> 01:13:23,280
arkani Hamed said

1884
01:13:27,530 --> 01:13:25,920
that there's this mistake that the

1885
01:13:29,149 --> 01:13:27,540
public has about physics which is that

1886
01:13:31,250 --> 01:13:29,159
almost every moment in time we need some

1887
01:13:34,130 --> 01:13:31,260
radically new paradigm that we have to

1888
01:13:36,410 --> 01:13:34,140

be revolutionary he said no what is

1889
01:13:38,689 --> 01:13:36,420
required is conservative revolutionarism

1890
01:13:40,970 --> 01:13:38,699
or revolutionary conservatism whichever

1891
01:13:43,370 --> 01:13:40,980
and what he meant by that is

1892
01:13:44,870 --> 01:13:43,380
well let's take a look at at Einstein

1893
01:13:46,729 --> 01:13:44,880
people say that with special relativity

1894
01:13:49,550 --> 01:13:46,739
what he did was extremely revolutionary

1895
01:13:51,290 --> 01:13:49,560
they said no he was revolutionary about

1896
01:13:53,990 --> 01:13:51,300
one aspect and was extremely

1897
01:13:55,370 --> 01:13:54,000
conservative about others he said these

1898
01:13:56,990 --> 01:13:55,380
are certain aspects that I want to hold

1899
01:13:58,790 --> 01:13:57,000
on to and here's what I'm willing to

1900
01:14:01,310 --> 01:13:58,800
give up and then he came up with his

1901
01:14:03,110 --> 01:14:01,320
theory do you see it as some people are

1902
01:14:05,209 --> 01:14:03,120
extremely conservative about locality

1903
01:14:06,830 --> 01:14:05,219
and they're willing to be extremely

1904
01:14:08,990 --> 01:14:06,840
revolutionary in other respects like

1905
01:14:10,610 --> 01:14:09,000
let's dismiss with statistical

1906
01:14:12,830 --> 01:14:10,620
Independence do you see it as that sort

1907
01:14:15,169 --> 01:14:12,840
of issue or is it something else I think

1908
01:14:17,209 --> 01:14:15,179
it's something else I I look you have to

1909
01:14:19,130 --> 01:14:17,219
remember the physicists of course

1910
01:14:23,689 --> 01:14:19,140
philosophers everybody are human beings

1911
01:14:25,250 --> 01:14:23,699
and and human beings have their oils

1912
01:14:27,110 --> 01:14:25,260
um

1913
01:14:29,390 --> 01:14:27,120

and

1914
01:14:32,750 --> 01:14:29,400
all right let me

1915
01:14:34,930 --> 01:14:32,760
I'm gonna illustrate this one of the one

1916
01:14:38,149 --> 01:14:34,940
of the physicists who early on

1917
01:14:39,709 --> 01:14:38,159
recognized and advertised Bell's result

1918
01:14:40,970 --> 01:14:39,719
because you know you have to bear in

1919
01:14:43,430 --> 01:14:40,980
mind that

1920
01:14:45,470 --> 01:14:43,440
that if if not for some kind of very

1921
01:14:47,810 --> 01:14:45,480
lucky things happening Bell's result

1922
01:14:49,550 --> 01:14:47,820
might have gone entirely buried and

1923
01:14:52,130 --> 01:14:49,560
nobody would have even known about it I

1924
01:14:55,270 --> 01:14:52,140
mean it was it was published in the

1925
01:14:57,890 --> 01:14:55,280
first volume of a brand new

1926
01:15:00,830 --> 01:14:57,900
a journal that went out of business

1927
01:15:02,450 --> 01:15:00,840
within a couple years

1928
01:15:03,850 --> 01:15:02,460
um so people wouldn't even know about

1929
01:15:07,310 --> 01:15:03,860
the journal

1930
01:15:10,130 --> 01:15:07,320
it happened to fall in the hands of of

1931
01:15:11,630 --> 01:15:10,140
Abner shimoni and shimoni read it and

1932
01:15:14,270 --> 01:15:11,640
understood how important it was and

1933
01:15:15,590 --> 01:15:14,280
shimoni happened to know John clauser

1934
01:15:17,209 --> 01:15:15,600
who was looking for an experimental

1935
01:15:19,130 --> 01:15:17,219
project okay there's a there's a whole

1936
01:15:22,610 --> 01:15:19,140
history here but it's a it's a very iffy

1937
01:15:25,250 --> 01:15:22,620
thing right that Bell's result could

1938
01:15:26,209 --> 01:15:25,260

have just completely disappeared

1939
01:15:28,910 --> 01:15:26,219
um

1940
01:15:30,550 --> 01:15:28,920
but one of the physicists who who early

1941
01:15:32,930 --> 01:15:30,560
on

1942
01:15:37,070 --> 01:15:32,940
understood the importance of Belle's

1943
01:15:39,770 --> 01:15:37,080
result was David merman and Merman was a

1944
01:15:41,330 --> 01:15:39,780
good popularizer and he wrote some

1945
01:15:42,770 --> 01:15:41,340
articles he also wrote articles that

1946
01:15:47,270 --> 01:15:42,780
were published even in philosophy

1947
01:15:52,070 --> 01:15:47,280
journals explaining what bell did

1948
01:15:53,810 --> 01:15:52,080
um and and the original Bell result the

1949
01:15:56,270 --> 01:15:53,820
one that Bell proves

1950
01:15:57,950 --> 01:15:56,280
is a statistical result it says if you

1951
01:15:59,209 --> 01:15:57,960
there's a certain kind of experiment if

1952
01:16:01,430 --> 01:15:59,219
you do it over and over and over and

1953
01:16:03,890 --> 01:16:01,440
over again you you then accumulate

1954
01:16:06,950 --> 01:16:03,900
statistics about correlations between

1955
01:16:09,050 --> 01:16:06,960
outcomes on these two sides and this

1956
01:16:11,390 --> 01:16:09,060
Bell inequality

1957
01:16:13,310 --> 01:16:11,400
puts mathematical constraints on how

1958
01:16:15,050 --> 01:16:13,320
strong those correlations can be and

1959
01:16:18,350 --> 01:16:15,060
that's what's violated

1960
01:16:19,910 --> 01:16:18,360
and uh merman said he always had a

1961
01:16:23,630 --> 01:16:19,920
suspicion

1962
01:16:26,930 --> 01:16:23,640
that the probabilistic nature of these

1963
01:16:28,550 --> 01:16:26,940

predictions was really essential

1964
01:16:32,689 --> 01:16:28,560
right that the fact that you were

1965
01:16:34,189 --> 01:16:32,699
dealing not with strict 100 predictions

1966
01:16:37,610 --> 01:16:34,199
but only

1967
01:16:39,890 --> 01:16:37,620
percentage predictions right was somehow

1968
01:16:42,590 --> 01:16:39,900
very deep to this result he said he

1969
01:16:45,350 --> 01:16:42,600
could never quite articulate one

1970
01:16:47,390 --> 01:16:45,360
and then some years later uh green

1971
01:16:49,070 --> 01:16:47,400
Burger horn and zeilinger came up with

1972
01:16:50,810 --> 01:16:49,080
this very nice example it's the one I

1973
01:16:52,729 --> 01:16:50,820
use all the time now instead of Belle's

1974
01:16:54,410 --> 01:16:52,739
original example which instead of

1975
01:16:57,229 --> 01:16:54,420
involving pairs of particles involves

1976
01:16:59,630 --> 01:16:57,239
triples of particles uh this is in my

1977
01:17:01,070 --> 01:16:59,640
book if anybody wants to read it um it's

1978
01:17:03,229 --> 01:17:01,080
a beautiful thing to be explained in

1979
01:17:04,910 --> 01:17:03,239
five minutes but the nice thing about it

1980
01:17:07,250 --> 01:17:04,920
is that the predictions there are not

1981
01:17:10,310 --> 01:17:07,260
statistical they're 100 predictions they

1982
01:17:12,350 --> 01:17:10,320
say according to Quantum Mechanics you

1983
01:17:14,209 --> 01:17:12,360
should get this kind of result

1984
01:17:17,870 --> 01:17:14,219
every time

1985
01:17:20,090 --> 01:17:17,880
right so if if it even fails once it's

1986
01:17:22,430 --> 01:17:20,100
it's Uncle you know quantum mechanics

1987
01:17:24,649 --> 01:17:22,440
has failed you know unless they're you

1988
01:17:26,510 --> 01:17:24,659

know experimental error but

1989
01:17:30,649 --> 01:17:26,520
and

1990
01:17:33,350 --> 01:17:30,659
when merman saw that

1991
01:17:35,149 --> 01:17:33,360
he appreciated he wrote a very nice

1992
01:17:37,070 --> 01:17:35,159
article about it and he said at the end

1993
01:17:39,950 --> 01:17:37,080
I used to think that the probabilities

1994
01:17:42,830 --> 01:17:39,960
here were really important I was wrong

1995
01:17:44,570 --> 01:17:42,840
okay I there you know this just shows I

1996
01:17:46,310 --> 01:17:44,580
was wrong because here you have a

1997
01:17:49,390 --> 01:17:46,320
locality result that doesn't involve

1998
01:17:52,370 --> 01:17:49,400
probabilities they're all one and zero

1999
01:17:54,290 --> 01:17:52,380
and you know you can't ask for more than

2000
01:17:57,530 --> 01:17:54,300
that from somebody okay he had his

2001
01:17:59,990 --> 01:17:57,540
suspicions he stated them publicly when

2002
01:18:01,970 --> 01:18:00,000
he got reasoned to see that that those

2003
01:18:04,250 --> 01:18:01,980
were wrong he retracted them publicly

2004
01:18:06,950 --> 01:18:04,260
and he wasn't upset about him why would

2005
01:18:09,110 --> 01:18:06,960
you be upset about it I mean I often say

2006
01:18:10,550 --> 01:18:09,120
the nicest feeling you can have when you

2007
01:18:11,870 --> 01:18:10,560
fall asleep at night is that you

2008
01:18:14,030 --> 01:18:11,880
understand something you didn't

2009
01:18:16,370 --> 01:18:14,040
understand in the morning or you've

2010
01:18:19,850 --> 01:18:16,380
corrected an error in your thinking

2011
01:18:22,370 --> 01:18:19,860
I mean people don't like to admit errors

2012
01:18:24,350 --> 01:18:22,380
to different degrees

2013
01:18:25,790 --> 01:18:24,360

um right and that's just human beings

2014
01:18:27,770 --> 01:18:25,800
right I mean that's true of all human

2015
01:18:30,770 --> 01:18:27,780
beings you have to

2016
01:18:33,350 --> 01:18:30,780
try to get familiar enough

2017
01:18:35,689 --> 01:18:33,360
with at least some of the content

2018
01:18:38,930 --> 01:18:35,699
that you can really make an independent

2019
01:18:41,870 --> 01:18:38,940
Judgment of your own about who who's

2020
01:18:44,990 --> 01:18:41,880
right and who's wrong and then start

2021
01:18:47,689 --> 01:18:45,000
more trusting the people who who are

2022
01:18:48,890 --> 01:18:47,699
right and and being more leery about the

2023
01:18:51,050 --> 01:18:48,900
people who are wrong there's nothing

2024
01:18:52,669 --> 01:18:51,060
else you can do it's unfortunate it's

2025
01:18:55,970 --> 01:18:52,679
hard work right

2026
01:18:58,850 --> 01:18:55,980
and and and anybody trying to pick up

2027
01:19:02,750 --> 01:18:58,860
physics from the kind of uh Public

2028
01:19:04,490 --> 01:19:02,760
Presentation is not gonna be in a

2029
01:19:06,110 --> 01:19:04,500
position very well to do that as I say

2030
01:19:09,890 --> 01:19:06,120
if you're interested in super

2031
01:19:13,430 --> 01:19:09,900
determinism get Bell's book read chapter

2032
01:19:16,610 --> 01:19:13,440
it's only four pages read chapter 12

2033
01:19:18,709 --> 01:19:16,620
read it carefully and think

2034
01:19:21,169 --> 01:19:18,719
think for yourself

2035
01:19:23,990 --> 01:19:21,179
and and ask yourself whether you think

2036
01:19:26,510 --> 01:19:24,000
denying the statistical Independence

2037
01:19:31,010 --> 01:19:26,520
assumption that he uses is something

2038
01:19:32,090 --> 01:19:31,020

that is it has any physical plausibility

2039
01:19:33,970 --> 01:19:32,100
um

2040
01:19:36,410 --> 01:19:33,980
that that

2041
01:19:38,750 --> 01:19:36,420
and and if you're wondering you know

2042
01:19:41,630 --> 01:19:38,760
that that's the best thing to do right

2043
01:19:44,770 --> 01:19:41,640
I'm not asked to take it on my word sure

2044
01:19:47,270 --> 01:19:44,780
sure so let's talk about the PBR theorem

2045
01:19:50,090 --> 01:19:47,280
do you see it as one of the landmark

2046
01:19:52,850 --> 01:19:50,100
theorems on par with bell or second or

2047
01:19:55,250 --> 01:19:52,860
even perhaps greater than Bells I I

2048
01:19:57,830 --> 01:19:55,260
would say I I think it's

2049
01:19:59,149 --> 01:19:57,840
it in a certain way as important as

2050
01:20:02,209 --> 01:19:59,159
Bell's result

2051
01:20:04,310 --> 01:20:02,219
but not as surprising

2052
01:20:06,110 --> 01:20:04,320
um that is not a surprising given Bell

2053
01:20:08,229 --> 01:20:06,120
that we already know about no no not as

2054
01:20:12,590 --> 01:20:08,239
surprising even before Bell

2055
01:20:14,149 --> 01:20:12,600
so let me say why I mean the PBR result

2056
01:20:17,209 --> 01:20:14,159
says

2057
01:20:19,850 --> 01:20:17,219
we use this thing the wave function this

2058
01:20:21,830 --> 01:20:19,860
mathematical object at the center of the

2059
01:20:25,010 --> 01:20:21,840
mathematical apparatus of quantum

2060
01:20:26,530 --> 01:20:25,020
mechanics everybody uses it to calculate

2061
01:20:29,270 --> 01:20:26,540
with

2062
01:20:31,250 --> 01:20:29,280
and again you know one question you

2063
01:20:32,930 --> 01:20:31,260

should ask yourself why is that right

2064
01:20:35,090 --> 01:20:32,940
why are we why are we using this thing

2065
01:20:37,610 --> 01:20:35,100
one possible answer is well because it's

2066
01:20:40,310 --> 01:20:37,620
a pretty good representation of the of

2067
01:20:43,669 --> 01:20:40,320
some actual physical reality

2068
01:20:47,570 --> 01:20:43,679
in an individual system in an individual

2069
01:20:50,330 --> 01:20:47,580
system right it it represents some

2070
01:20:52,850 --> 01:20:50,340
physical characteristic of the

2071
01:20:55,010 --> 01:20:52,860
individual system in front of me

2072
01:20:56,149 --> 01:20:55,020
an irrelevant physical characteristic

2073
01:20:59,630 --> 01:20:56,159
right

2074
01:21:04,850 --> 01:21:02,930
even apart from Bell if you ask well

2075
01:21:06,950 --> 01:21:04,860
should I take this wave function

2076
01:21:09,290 --> 01:21:06,960
seriously in that sense or should I

2077
01:21:11,630 --> 01:21:09,300
rather think it's something merely

2078
01:21:13,669 --> 01:21:11,640
epistemic that so the wave function is

2079
01:21:15,050 --> 01:21:13,679
kind of for a single particle let's just

2080
01:21:16,910 --> 01:21:15,060
talk about a single particle because

2081
01:21:19,010 --> 01:21:16,920
it's easier although it's a little

2082
01:21:20,930 --> 01:21:19,020
misleading single particle the wave

2083
01:21:22,729 --> 01:21:20,940
function is defined over all of space so

2084
01:21:25,010 --> 01:21:22,739
you can sort of think of it like a field

2085
01:21:26,630 --> 01:21:25,020
and it's spread out and and the

2086
01:21:28,310 --> 01:21:26,640
Schrodinger equation tells you how it

2087
01:21:30,590 --> 01:21:28,320
evolves and it evolves by a wave

2088
01:21:33,169 --> 01:21:30,600

equation good

2089
01:21:35,450 --> 01:21:33,179
okay is there anything in any if I send

2090
01:21:38,930 --> 01:21:35,460
a single particle through a two-slit

2091
01:21:43,669 --> 01:21:41,750
um I represent that single particle in

2092
01:21:45,410 --> 01:21:43,679
part using a wave function and the wave

2093
01:21:47,390 --> 01:21:45,420
function is spread out and the wave

2094
01:21:49,490 --> 01:21:47,400
equation carries that wave function

2095
01:21:52,430 --> 01:21:49,500
through both slips

2096
01:21:54,050 --> 01:21:52,440
and from there each slit produces its

2097
01:21:56,209 --> 01:21:54,060
own as it were a little wave and then

2098
01:21:59,510 --> 01:21:56,219
they interfere like water waves and you

2099
01:22:03,050 --> 01:21:59,520
get this interference pattern yeah

2100
01:22:04,910 --> 01:22:03,060
and physically what we see if I do this

2101
01:22:08,270 --> 01:22:04,920
two-set experiment over and over again

2102
01:22:09,830 --> 01:22:08,280
with individual single particles is what

2103
01:22:11,990 --> 01:22:09,840
shows up on the screen is this

2104
01:22:15,709 --> 01:22:12,000
interference pattern with these

2105
01:22:19,130 --> 01:22:15,719
bands through it light and dark bands

2106
01:22:22,130 --> 01:22:19,140
now as soon as you see that you say gosh

2107
01:22:24,410 --> 01:22:22,140
okay well that wave function must really

2108
01:22:27,229 --> 01:22:24,420
represent something physical that does

2109
01:22:30,709 --> 01:22:27,239
interact with both slits that's how

2110
01:22:33,050 --> 01:22:30,719
interference works right if each

2111
01:22:36,530 --> 01:22:33,060
individual particle merely went through

2112
01:22:39,470 --> 01:22:36,540
one slit and nothing nothing

2113
01:22:41,270 --> 01:22:39,480

interacted with the other sled

2114
01:22:43,370 --> 01:22:41,280
then you couldn't possibly get this kind

2115
01:22:46,430 --> 01:22:43,380
of interference so the idea that you

2116
01:22:49,189 --> 01:22:46,440
should take the wave function seriously

2117
01:22:51,530 --> 01:22:49,199
as representing a real physical feature

2118
01:22:53,330 --> 01:22:51,540
of individual systems

2119
01:22:54,830 --> 01:22:53,340
so nothing to do with anybody's

2120
01:22:57,110 --> 01:22:54,840
knowledge nothing to do with

2121
01:22:59,270 --> 01:22:57,120
epistemology nothing to do with

2122
01:23:01,910 --> 01:22:59,280
statistical characteristics of large

2123
01:23:04,790 --> 01:23:01,920
groups of systems

2124
01:23:07,209 --> 01:23:04,800
it it represents some physical reality

2125
01:23:10,010 --> 01:23:07,219
that pertains to an individual system

2126
01:23:13,430 --> 01:23:10,020
that's just from two split interference

2127
01:23:15,530 --> 01:23:13,440
everybody should believe that

2128
01:23:17,510 --> 01:23:15,540
and everybody I know does believe it

2129
01:23:19,610 --> 01:23:17,520
this was not something the people that I

2130
01:23:22,010 --> 01:23:19,620
know that work in foundations nobody

2131
01:23:23,689 --> 01:23:22,020
ever questioned that because you just

2132
01:23:25,189 --> 01:23:23,699
say just the two now two slit

2133
01:23:27,169 --> 01:23:25,199
interference does not violate Bell's

2134
01:23:29,090 --> 01:23:27,179
inequality so this is not non-locality

2135
01:23:30,649 --> 01:23:29,100
this is a different thing

2136
01:23:32,450 --> 01:23:30,659
and this is again another place where

2137
01:23:34,610 --> 01:23:32,460
you know Feynman makes a mistake when he

2138
01:23:36,110 --> 01:23:34,620

says well he wrote this before Belle but

2139
01:23:38,030 --> 01:23:36,120
he says all the mysteries of quantum

2140
01:23:39,830 --> 01:23:38,040
mechanics are somehow packaged into two

2141
01:23:42,169 --> 01:23:39,840
split no they're not

2142
01:23:45,350 --> 01:23:42,179
because Bell isn't

2143
01:23:48,410 --> 01:23:45,360
but if you just think about those kinds

2144
01:23:51,590 --> 01:23:48,420
of familiar interference experiments

2145
01:23:54,550 --> 01:23:51,600
okay done with single particles and

2146
01:23:56,810 --> 01:23:54,560
where you accumulate the data over time

2147
01:23:59,209 --> 01:23:56,820
anybody looking at that is going to say

2148
01:24:00,649 --> 01:23:59,219
gosh that wave function must represent a

2149
01:24:02,870 --> 01:24:00,659
real physical characteristic of

2150
01:24:04,610 --> 01:24:02,880
individual systems now what the PBR

2151
01:24:07,610 --> 01:24:04,620
theorem does

2152
01:24:10,490 --> 01:24:07,620
is it gives you something even sharper

2153
01:24:11,750 --> 01:24:10,500
right it says if you if despite all that

2154
01:24:13,910 --> 01:24:11,760
you want to think that there's something

2155
01:24:16,370 --> 01:24:13,920
epistemic about the wave function that

2156
01:24:18,229 --> 01:24:16,380
it doesn't really represent physical

2157
01:24:20,870 --> 01:24:18,239
reality of the individual system it

2158
01:24:23,870 --> 01:24:20,880
somehow reflects your information or

2159
01:24:25,729 --> 01:24:23,880
something like that then the PBR this is

2160
01:24:27,709 --> 01:24:25,739
also called cubism or no well that's

2161
01:24:29,570 --> 01:24:27,719
sort of what the cube is said cubism is

2162
01:24:31,550 --> 01:24:29,580
I mean cubism is a very difficult

2163
01:24:34,189 --> 01:24:31,560

Doctrine to even understand what it's

2164
01:24:37,130 --> 01:24:34,199
claiming let's leave it aside for the

2165
01:24:40,490 --> 01:24:37,140
moment but someone you know a common

2166
01:24:42,950 --> 01:24:40,500
idea was that no the wave function is

2167
01:24:44,689 --> 01:24:42,960
kind of spread out not because anything

2168
01:24:47,750 --> 01:24:44,699
physical was spread out but because

2169
01:24:51,169 --> 01:24:47,760
we're ignorant about where something is

2170
01:24:53,330 --> 01:24:51,179
right and the spread outness reflects us

2171
01:24:55,790 --> 01:24:53,340
not knowing where it is not that there

2172
01:24:58,970 --> 01:24:55,800
is something in these different regions

2173
01:25:00,649 --> 01:24:58,980
so uh I think anybody who just thought

2174
01:25:02,510 --> 01:25:00,659
about two slit would say no that can't

2175
01:25:05,090 --> 01:25:02,520
be right it can't be merely epistemic

2176
01:25:06,830 --> 01:25:05,100
and again David merman makes this point

2177
01:25:09,290 --> 01:25:06,840
in one article he made the point very

2178
01:25:10,490 --> 01:25:09,300
nice with a dialogue a kind of dialogue

2179
01:25:13,610 --> 01:25:10,500
with somebody who's trying to be

2180
01:25:15,470 --> 01:25:13,620
epistemic and they say oh you know the

2181
01:25:18,010 --> 01:25:15,480
wave function spreading out is just a

2182
01:25:20,930 --> 01:25:18,020
matter of of our ignorance

2183
01:25:22,910 --> 01:25:20,940
and and then in in response somebody

2184
01:25:24,590 --> 01:25:22,920
says so it's our ignorance that goes

2185
01:25:27,649 --> 01:25:24,600
through the two slits

2186
01:25:30,110 --> 01:25:27,659
right interferes right and that makes no

2187
01:25:32,630 --> 01:25:30,120
sense right I mean something physical is

2188
01:25:37,850 --> 01:25:32,640

interacting with both slits

2189
01:25:40,910 --> 01:25:37,860
um it has to be so what what PBR did was

2190
01:25:43,010 --> 01:25:40,920
they they took the observation that I

2191
01:25:46,250 --> 01:25:43,020
made which is not a proof

2192
01:25:48,830 --> 01:25:46,260
and they gave a sharp definition of what

2193
01:25:51,950 --> 01:25:48,840
it is to regard the wave function is

2194
01:25:54,910 --> 01:25:51,960
representing something real about the

2195
01:25:58,010 --> 01:25:54,920
individual system as opposed to

2196
01:26:00,229 --> 01:25:58,020
representing something about merely our

2197
01:26:03,410 --> 01:26:00,239
knowledge of the system

2198
01:26:04,310 --> 01:26:03,420
and then they said well

2199
01:26:07,430 --> 01:26:04,320
um

2200
01:26:08,450 --> 01:26:07,440
if you believe it's epistemic by our

2201
01:26:10,570 --> 01:26:08,460
definition

2202
01:26:12,950 --> 01:26:10,580
here's an experiment

2203
01:26:14,330 --> 01:26:12,960
that you'll make the wrong predictions

2204
01:26:15,649 --> 01:26:14,340
about I mean you'll make predictions

2205
01:26:17,770 --> 01:26:15,659
you'll have to make predictions that

2206
01:26:20,330 --> 01:26:17,780
violate quantum mechanical predictions

2207
01:26:22,070 --> 01:26:20,340
and by the way they also use statistical

2208
01:26:23,750 --> 01:26:22,080
Independence assumption in their proof

2209
01:26:25,850 --> 01:26:23,760
but that's fine because the statistical

2210
01:26:27,290 --> 01:26:25,860
Independence function is fine right you

2211
01:26:29,090 --> 01:26:27,300
know I've got a problem with that they

2212
01:26:31,070 --> 01:26:29,100
they use one as well

2213
01:26:33,050 --> 01:26:31,080

um and it's a nice proof I mean I and

2214
01:26:34,550 --> 01:26:33,060
people who reacted at the time who said

2215
01:26:36,649 --> 01:26:34,560
this is the most important proof since

2216
01:26:38,570 --> 01:26:36,659
Bell I think I think David Wallace said

2217
01:26:40,669 --> 01:26:38,580
that I think he's right I think if

2218
01:26:43,070 --> 01:26:40,679
you're doing foundations

2219
01:26:45,110 --> 01:26:43,080
it just I mean you could say it was the

2220
01:26:46,610 --> 01:26:45,120
last nail in the coffin and the coffin

2221
01:26:48,910 --> 01:26:46,620
was already shut that you shouldn't have

2222
01:26:51,169 --> 01:26:48,920
been an epistemicist in the first place

2223
01:26:53,209 --> 01:26:51,179
for you know straightforward physical

2224
01:26:55,550 --> 01:26:53,219
reasons right how do you explain these

2225
01:26:59,209 --> 01:26:55,560
interference bands

2226
01:27:01,970 --> 01:26:59,219
um but if somebody again wanted to be

2227
01:27:04,910 --> 01:27:01,980
very recalcitrant and and and stubborn

2228
01:27:07,370 --> 01:27:04,920
and say no no no I just really think

2229
01:27:09,709 --> 01:27:07,380
there's something epistemic about this

2230
01:27:12,530 --> 01:27:09,719
wave function the PBR theorem kind of

2231
01:27:14,390 --> 01:27:12,540
puts that to rest and so you can move on

2232
01:27:15,649 --> 01:27:14,400
so yeah I think it's very important I

2233
01:27:20,149 --> 01:27:15,659
think it's an extremely important thing

2234
01:27:24,110 --> 01:27:20,159
I think as I say it's not as astonishing

2235
01:27:25,310 --> 01:27:24,120
in what it's claiming as Bell there's a

2236
01:27:26,990 --> 01:27:25,320
word a phrase that you use called

2237
01:27:28,850 --> 01:27:27,000
foundations of quantum mechanics or

2238
01:27:30,430 --> 01:27:28,860

foundations but that's the standard for

2239
01:27:33,169 --> 01:27:30,440
foundations of quantum mechanics

2240
01:27:34,910 --> 01:27:33,179
infamously when you go to a Physics

2241
01:27:36,050 --> 01:27:34,920
course if you get a Physics degree and

2242
01:27:37,850 --> 01:27:36,060
you ask about well what does this

2243
01:27:39,590 --> 01:27:37,860
so-and-so mean especially when it comes

2244
01:27:41,629 --> 01:27:39,600
to Quantum field Theory quantum

2245
01:27:43,310 --> 01:27:41,639
mechanics they say hey go to a

2246
01:27:45,649 --> 01:27:43,320
philosophy Department essentially what

2247
01:27:47,149 --> 01:27:45,659
I'm asking is what textbooks should one

2248
01:27:49,430 --> 01:27:47,159
read let's say they're at The Graduate

2249
01:27:51,709 --> 01:27:49,440
level in order to become familiar with

2250
01:27:53,209 --> 01:27:51,719
Quantum foundations like is there a set

2251
01:27:55,010 --> 01:27:53,219
of five books that you feel like hey

2252
01:27:57,770 --> 01:27:55,020
read these in this order that gives you

2253
01:28:00,530 --> 01:27:57,780
a great introduction well I mean the

2254
01:28:03,530 --> 01:28:00,540
thing I I was once did a did a thing at

2255
01:28:05,990 --> 01:28:03,540
the end they ask you name five books in

2256
01:28:08,450 --> 01:28:06,000
your field that you would recommend

2257
01:28:11,270 --> 01:28:08,460
and I said and I was only half joking I

2258
01:28:14,330 --> 01:28:11,280
would say I I said okay get this book

2259
01:28:16,189 --> 01:28:14,340
and read it five times okay that I mean

2260
01:28:17,689 --> 01:28:16,199
I mean you know this is a collection of

2261
01:28:19,970 --> 01:28:17,699
Articles and there are different levels

2262
01:28:23,689 --> 01:28:19,980
and it's not a single presentation but

2263
01:28:25,129 --> 01:28:23,699

Belle is really On Target really really

2264
01:28:26,689 --> 01:28:25,139
beautifully out there and you have to be

2265
01:28:29,390 --> 01:28:26,699
careful when you read him because he's

2266
01:28:31,250 --> 01:28:29,400
he's so precise in the way he writes

2267
01:28:32,810 --> 01:28:31,260
that he'll say something once and he

2268
01:28:34,010 --> 01:28:32,820
won't beat you over the head with it a

2269
01:28:36,350 --> 01:28:34,020
hundred times and you have to pay

2270
01:28:38,209 --> 01:28:36,360
attention I beat people over the head

2271
01:28:39,590 --> 01:28:38,219
right my technique as I say is to use a

2272
01:28:42,169 --> 01:28:39,600
two by four and whack you over the head

2273
01:28:44,570 --> 01:28:42,179
a hundred times and say the same thing

2274
01:28:46,970 --> 01:28:44,580
um Bells using a scalpel and sort of

2275
01:28:49,129 --> 01:28:46,980
just like that like direct yeah I mean

2276
01:28:50,930 --> 01:28:49,139
it's just I mean it's beautiful and he's

2277
01:28:53,030 --> 01:28:50,940
really again if you're worried about

2278
01:28:55,790 --> 01:28:53,040
super determinism just read this four

2279
01:28:58,850 --> 01:28:55,800
page paper of bells it's all there

2280
01:29:01,070 --> 01:28:58,860
um so you should read that if you're if

2281
01:29:02,629 --> 01:29:01,080
you're used to a physics if you're a

2282
01:29:04,970 --> 01:29:02,639
physics major and you're used to a

2283
01:29:08,689 --> 01:29:04,980
physics presentation there's this nice

2284
01:29:11,390 --> 01:29:08,699
book by Travis Morrison that came out I

2285
01:29:12,110 --> 01:29:11,400
don't know five years ago

2286
01:29:13,970 --> 01:29:12,120
um

2287
01:29:16,490 --> 01:29:13,980
I think it's called foundations of

2288
01:29:18,470 --> 01:29:16,500

quantum mechanics but it's really

2289
01:29:20,510 --> 01:29:18,480
for

2290
01:29:23,110 --> 01:29:20,520
physics students

2291
01:29:26,209 --> 01:29:23,120
as an introduction to

2292
01:29:28,610 --> 01:29:26,219
quantum theory but with attention to the

2293
01:29:32,209 --> 01:29:28,620
historical and historical background and

2294
01:29:33,890 --> 01:29:32,219
conceptual detail that's not in a normal

2295
01:29:35,990 --> 01:29:33,900
physics book

2296
01:29:38,990 --> 01:29:36,000
and it goes over interpretations as well

2297
01:29:44,090 --> 01:29:42,470
um then you know David Albert who people

2298
01:29:45,950 --> 01:29:44,100
may not know got his degree in

2299
01:29:47,570 --> 01:29:45,960
theoretical physics from Rockefeller

2300
01:29:49,850 --> 01:29:47,580
University but was interested in

2301
01:29:51,290 --> 01:29:49,860
foundations and therefore switched to a

2302
01:29:53,149 --> 01:29:51,300
philosophy department so he's in the

2303
01:29:54,830 --> 01:29:53,159
philosophy Department of Colombia you

2304
01:29:56,510 --> 01:29:54,840
know he wrote a book which is more

2305
01:29:58,790 --> 01:29:56,520
philosophical and a little more out

2306
01:30:00,830 --> 01:29:58,800
there in certain ways called quantum

2307
01:30:04,149 --> 01:30:00,840
mechanics and experience

2308
01:30:06,350 --> 01:30:04,159
and it's not you know it it's not like

2309
01:30:09,050 --> 01:30:06,360
norson's book which is aimed at physics

2310
01:30:11,570 --> 01:30:09,060
students it's it's aimed I mean David's

2311
01:30:13,669 --> 01:30:11,580
trying to take as much math out of it

2312
01:30:15,169 --> 01:30:13,679
as possible

2313
01:30:16,850 --> 01:30:15,179

um and kind of look at the conceptual

2314
01:30:18,410 --> 01:30:16,860
issues

2315
01:30:20,270 --> 01:30:18,420
um I mean you have my book which is

2316
01:30:22,490 --> 01:30:20,280
philosophy of physics quantum theory

2317
01:30:25,370 --> 01:30:22,500
which is you know it's more math than

2318
01:30:27,169 --> 01:30:25,380
David has and less math than Travis has

2319
01:30:28,910 --> 01:30:27,179
all right it's in between the two and

2320
01:30:30,709 --> 01:30:28,920
every one of the books you mentioned for

2321
01:30:32,689 --> 01:30:30,719
those who are watching that'll be in the

2322
01:30:36,950 --> 01:30:32,699
description

2323
01:30:39,110 --> 01:30:36,960
um I I I think you know between those

2324
01:30:42,950 --> 01:30:39,120
four books

2325
01:30:43,729 --> 01:30:42,960
you certainly have everything you need

2326
01:30:46,250 --> 01:30:43,739
um

2327
01:30:49,550 --> 01:30:46,260
and the book by you what was it called

2328
01:30:52,129 --> 01:30:49,560
velocity of physics colon quantum theory

2329
01:30:53,629 --> 01:30:52,139
there's a little set of of books it's a

2330
01:30:55,209 --> 01:30:53,639
it's a series of books that are supposed

2331
01:30:58,129 --> 01:30:55,219
to be introductory books for

2332
01:30:59,930 --> 01:30:58,139
philosophers to different issues and I

2333
01:31:01,850 --> 01:30:59,940
did the philosophy of physics one but

2334
01:31:03,410 --> 01:31:01,860
there are two volumes one is space and

2335
01:31:06,050 --> 01:31:03,420
time which is an introduction to

2336
01:31:07,250 --> 01:31:06,060
space-time Theory and relativity and the

2337
01:31:09,649 --> 01:31:07,260
other is quantum theory which is about

2338
01:31:11,209 --> 01:31:09,659

Quantum Theory and Someday I'm gonna do

2339
01:31:12,590 --> 01:31:11,219
a third part or put them all together

2340
01:31:14,810 --> 01:31:12,600
and do something on statistical

2341
01:31:17,510 --> 01:31:14,820
explanation and thermodynamics and

2342
01:31:19,430 --> 01:31:17,520
entropy and stuff but that's somewhere

2343
01:31:23,270 --> 01:31:19,440
in the future

2344
01:31:25,729 --> 01:31:23,280
what the heck is a Bible a Bible be able

2345
01:31:27,590 --> 01:31:25,739
yeah so what the heck is a biable and

2346
01:31:29,629 --> 01:31:27,600
why did Belle invent this terminology

2347
01:31:30,890 --> 01:31:29,639
because to me as an outsider just sounds

2348
01:31:34,250 --> 01:31:30,900
like something that exists some

2349
01:31:36,850 --> 01:31:34,260
ontological object that's all it is but

2350
01:31:41,750 --> 01:31:36,860
that's you see

2351
01:31:44,149 --> 01:31:41,760
the word ontology and I can testify from

2352
01:31:45,770 --> 01:31:44,159
personal experience it scares physicists

2353
01:31:47,930 --> 01:31:45,780
right you say what's the ontology of

2354
01:31:49,850 --> 01:31:47,940
their Theory and they go like ontology

2355
01:31:50,870 --> 01:31:49,860
okay because they didn't learn Greek

2356
01:31:54,709 --> 01:31:50,880
right

2357
01:31:57,410 --> 01:31:54,719
um an ontology just means in Greek Anta

2358
01:31:59,870 --> 01:31:57,420
are the things that exist and logos is

2359
01:32:02,090 --> 01:31:59,880
an account so the ontology of your

2360
01:32:04,870 --> 01:32:02,100
theory is tell me what your theory

2361
01:32:08,149 --> 01:32:04,880
postulates to exist

2362
01:32:09,590 --> 01:32:08,159
and Bell wanted a word for the same

2363
01:32:12,290 --> 01:32:09,600

thing now he could have used ontology

2364
01:32:13,669 --> 01:32:12,300
but he didn't I don't know why

2365
01:32:15,169 --> 01:32:13,679
um I mean he doesn't have a philosophy

2366
01:32:18,110 --> 01:32:15,179
background maybe it didn't occur to him

2367
01:32:20,209 --> 01:32:18,120
and he even says in a paper he says in

2368
01:32:22,790 --> 01:32:20,219
the theory of vocal beibles he said well

2369
01:32:26,390 --> 01:32:22,800
he yeah he wanted a word

2370
01:32:28,610 --> 01:32:26,400
whose route was to be or to exist as

2371
01:32:31,430 --> 01:32:28,620
opposed to observable I mean what he was

2372
01:32:33,229 --> 01:32:31,440
doing was setting a contrast with the

2373
01:32:35,750 --> 01:32:33,239
term observable

2374
01:32:38,030 --> 01:32:35,760
because so many physicists would say oh

2375
01:32:41,330 --> 01:32:38,040
physics is about observables observables

2376
01:32:45,229 --> 01:32:41,340
observables and Bell said no no

2377
01:32:46,490 --> 01:32:45,239
it should be about be a bulls things

2378
01:32:50,450 --> 01:32:46,500
that exist

2379
01:32:52,970 --> 01:32:50,460
I mean he said he considered be ER b-e

2380
01:32:56,450 --> 01:32:52,980
hyphen e r but then that looks like deer

2381
01:33:00,110 --> 01:32:56,460
right and then he he he on the model of

2382
01:33:01,669 --> 01:33:00,120
observable he put b a bull

2383
01:33:03,709 --> 01:33:01,679
um it's you know I would just call it

2384
01:33:04,790 --> 01:33:03,719
the ontology of the theory but for

2385
01:33:06,350 --> 01:33:04,800
phosphorus would just call it the

2386
01:33:07,790 --> 01:33:06,360
ontology of the theory and physicists

2387
01:33:09,410 --> 01:33:07,800
should just get used to it's you know

2388
01:33:11,510 --> 01:33:09,420

it's but you can call it the Bibles it's

2389
01:33:14,330 --> 01:33:11,520
fine because Belle used that

2390
01:33:15,470 --> 01:33:14,340
um it's just what what is your physical

2391
01:33:18,229 --> 01:33:15,480
Theory

2392
01:33:20,149 --> 01:33:18,239
postulate to physically exist now this

2393
01:33:21,709 --> 01:33:20,159
is a question which would be the first

2394
01:33:22,669 --> 01:33:21,719
question it's not a philosophical

2395
01:33:24,830 --> 01:33:22,679
question

2396
01:33:26,689 --> 01:33:24,840
it's not oh philosophers are interested

2397
01:33:28,729 --> 01:33:26,699
in that no physicists right that's the

2398
01:33:30,770 --> 01:33:28,739
founding that's what your physics is

2399
01:33:32,810 --> 01:33:30,780
actually postulating to physically exist

2400
01:33:34,490 --> 01:33:32,820
right it's the first question you should

2401
01:33:36,530 --> 01:33:34,500
ask of any physical theory if you want

2402
01:33:39,830 --> 01:33:36,540
to understand it what does it postulate

2403
01:33:43,370 --> 01:33:39,840
to actually exist and unfortunately

2404
01:33:45,470 --> 01:33:43,380
because foundations of physics does not

2405
01:33:47,090 --> 01:33:45,480
is not part of a standard physics

2406
01:33:49,610 --> 01:33:47,100
education

2407
01:33:51,350 --> 01:33:49,620
which it isn't

2408
01:33:53,270 --> 01:33:51,360
um physicists get very nervous around

2409
01:33:55,550 --> 01:33:53,280
questions like this and sometimes they

2410
01:33:57,649 --> 01:33:55,560
they suggest answers that don't kind of

2411
01:33:59,629 --> 01:33:57,659
make any sense so there's a physicist of

2412
01:34:00,890 --> 01:33:59,639
why will Who Remain unnamed who was

2413
01:34:03,709 --> 01:34:00,900

asked this question at one of our

2414
01:34:05,689 --> 01:34:03,719
conferences well what's the you know

2415
01:34:07,129 --> 01:34:05,699
what are the Bibles of your theory what

2416
01:34:09,530 --> 01:34:07,139
does your theory postulate and came up

2417
01:34:10,790 --> 01:34:09,540
with the answer matrices and you want to

2418
01:34:12,770 --> 01:34:10,800
say no no that's not even in the right

2419
01:34:15,410 --> 01:34:12,780
ballpark right a matrix is a

2420
01:34:17,629 --> 01:34:15,420
mathematical object okay I mean a matrix

2421
01:34:19,729 --> 01:34:17,639
is a set of numbers in an array you're

2422
01:34:22,370 --> 01:34:19,739
not going to tell me the world the

2423
01:34:25,010 --> 01:34:22,380
physical world is made up of sets of

2424
01:34:28,490 --> 01:34:25,020
numbers in an array well if your max

2425
01:34:32,149 --> 01:34:28,500
tegmark well yeah I mean yes yes

2426
01:34:34,669 --> 01:34:32,159
take Mark exactly okay I mean you can

2427
01:34:38,330 --> 01:34:34,679
talk about and this is a real confusion

2428
01:34:40,990 --> 01:34:38,340
it to me I mean it makes when when Max

2429
01:34:43,610 --> 01:34:41,000
goes way out and says

2430
01:34:47,149 --> 01:34:43,620
the world's just

2431
01:34:49,850 --> 01:34:47,159
has a mathematical reality and the the

2432
01:34:51,590 --> 01:34:49,860
physical world has no reality that's any

2433
01:34:54,890 --> 01:34:51,600
different than any other mathematical

2434
01:34:57,709 --> 01:34:54,900
object so every mathematical object is

2435
01:34:59,510 --> 01:34:57,719
physically I mean again there's a

2436
01:35:01,970 --> 01:34:59,520
certain point at which

2437
01:35:04,010 --> 01:35:01,980
quite honestly you just say I don't

2438
01:35:05,750 --> 01:35:04,020

really want to spend my time

2439
01:35:07,729 --> 01:35:05,760
with this

2440
01:35:11,629 --> 01:35:07,739
it's just you know no there's a physical

2441
01:35:13,970 --> 01:35:11,639
world right it's true that we can make

2442
01:35:16,070 --> 01:35:13,980
really good predictions about it using

2443
01:35:18,169 --> 01:35:16,080
some mathematical representations and

2444
01:35:19,970 --> 01:35:18,179
that's a good thing to think about and

2445
01:35:21,950 --> 01:35:19,980
why those mathematical representations

2446
01:35:23,570 --> 01:35:21,960
are so effective that's a really good

2447
01:35:25,310 --> 01:35:23,580
thing to do but what you're thinking

2448
01:35:27,250 --> 01:35:25,320
about when you think about that is okay

2449
01:35:30,830 --> 01:35:27,260
what

2450
01:35:34,250 --> 01:35:30,840
might the physical world be like

2451
01:35:37,070 --> 01:35:34,260
such that this mathematics

2452
01:35:39,590 --> 01:35:37,080
makes such good predictions and that's

2453
01:35:43,070 --> 01:35:39,600
why I said that's why I like geometry

2454
01:35:46,990 --> 01:35:43,080
because one in in the case of geometry

2455
01:35:50,149 --> 01:35:47,000
it at least a possible answer is this

2456
01:35:51,910 --> 01:35:50,159
abstract geometry is such a good

2457
01:35:55,430 --> 01:35:51,920
representation of the physical world

2458
01:35:57,350 --> 01:35:55,440
because the world literally has that

2459
01:35:59,930 --> 01:35:57,360
geometrical structure

2460
01:36:01,070 --> 01:35:59,940
right then of course it's going to be

2461
01:36:02,510 --> 01:36:01,080
pretty good at making predictions

2462
01:36:04,370 --> 01:36:02,520
because you've got it right you know

2463
01:36:06,290 --> 01:36:04,380

you've got a good representation of the

2464
01:36:08,330 --> 01:36:06,300
way it really is and in the case of

2465
01:36:10,750 --> 01:36:08,340
geometry I can understand that as a

2466
01:36:13,129 --> 01:36:10,760
possibility in the case of you know

2467
01:36:15,050 --> 01:36:13,139
pure number Theory I don't understand

2468
01:36:17,629 --> 01:36:15,060
what it would be to say look the world

2469
01:36:20,270 --> 01:36:17,639
really is is has its numerical structure

2470
01:36:21,649 --> 01:36:20,280
I don't know I just don't understand it

2471
01:36:23,750 --> 01:36:21,659
um I can't get I can't wrap my head

2472
01:36:26,149 --> 01:36:23,760
around what would even mean

2473
01:36:27,649 --> 01:36:26,159
uh going back to that geometrical

2474
01:36:29,209 --> 01:36:27,659
structure that you were referencing in

2475
01:36:30,890 --> 01:36:29,219
the beginning so is that something that

2476
01:36:32,390 --> 01:36:30,900
you're currently working on or is there

2477
01:36:34,370 --> 01:36:32,400
paper that you can point people to to

2478
01:36:37,010 --> 01:36:34,380
learn more about it's something I mean I

2479
01:36:38,810 --> 01:36:37,020
I so I wrote a book

2480
01:36:41,810 --> 01:36:38,820
called New Foundations for physical

2481
01:36:43,010 --> 01:36:41,820
geometry colon the theory of linear

2482
01:36:45,290 --> 01:36:43,020
structures

2483
01:36:47,149 --> 01:36:45,300
um that came out a while ago and that

2484
01:36:50,330 --> 01:36:47,159
was a way of

2485
01:36:53,510 --> 01:36:50,340
trying to cover the same content or

2486
01:36:56,750 --> 01:36:53,520
conceptual territory that's covered by

2487
01:36:58,430 --> 01:36:56,760
standard topology uh points at topology

2488
01:37:00,110 --> 01:36:58,440

but in a different way using a different

2489
01:37:01,490 --> 01:37:00,120
Foundation

2490
01:37:03,229 --> 01:37:01,500
um

2491
01:37:05,450 --> 01:37:03,239
and there was always supposed to be a

2492
01:37:07,430 --> 01:37:05,460
second volume to that book so the first

2493
01:37:09,110 --> 01:37:07,440
volume was just pure math and the second

2494
01:37:11,510 --> 01:37:09,120
volume was supposed to be application to

2495
01:37:12,350 --> 01:37:11,520
physics and I intended to write that and

2496
01:37:13,729 --> 01:37:12,360
I thought it was going to be very

2497
01:37:16,010 --> 01:37:13,739
straightforward

2498
01:37:17,629 --> 01:37:16,020
and I was writing away at it and then I

2499
01:37:19,250 --> 01:37:17,639
was teaching and then I got interested

2500
01:37:21,169 --> 01:37:19,260
because one of the things that happens

2501
01:37:23,209 --> 01:37:21,179
in the first book Is I develop a way of

2502
01:37:25,250 --> 01:37:23,219
thinking about topology which applies

2503
01:37:27,229 --> 01:37:25,260
both for continua and for discrete

2504
01:37:29,330 --> 01:37:27,239
spaces because the standard

2505
01:37:31,310 --> 01:37:29,340
Point set topology doesn't really work

2506
01:37:33,530 --> 01:37:31,320
well in a discrete setting it just gives

2507
01:37:35,870 --> 01:37:33,540
you kind of trivial answers

2508
01:37:37,930 --> 01:37:35,880
um anyway I got interested in this idea

2509
01:37:40,070 --> 01:37:37,940
of discrete geometry and then I started

2510
01:37:41,810 --> 01:37:40,080
developing this thing I call full

2511
01:37:45,950 --> 01:37:41,820
discrete geometry and so this will

2512
01:37:49,610 --> 01:37:45,960
eventually come out as the second volume

2513
01:37:53,149 --> 01:37:49,620

of New Foundations of physical geometry

2514
01:37:54,590 --> 01:37:53,159
uh I can't say exactly when I mean I've

2515
01:37:56,629 --> 01:37:54,600
got six chapters that are all about

2516
01:37:59,750 --> 01:37:56,639
spatial structure and a few chapters now

2517
01:38:02,750 --> 01:37:59,760
about adding time in for space time and

2518
01:38:04,370 --> 01:38:02,760
I I have some really exciting recent

2519
01:38:06,590 --> 01:38:04,380
results which I was talking about which

2520
01:38:09,169 --> 01:38:06,600
are not published but but if you're

2521
01:38:11,270 --> 01:38:09,179
interested I've given the talk

2522
01:38:13,430 --> 01:38:11,280
a lot of times in fact I just gave the

2523
01:38:15,290 --> 01:38:13,440
talk for the International Space Science

2524
01:38:16,610 --> 01:38:15,300
Institute and they've put it up on the

2525
01:38:20,990 --> 01:38:16,620
web

2526
01:38:25,970 --> 01:38:23,810
um so yeah that that I mean I've got

2527
01:38:29,990 --> 01:38:25,980
more work to do

2528
01:38:31,430 --> 01:38:30,000
to finish that book I kind of see how

2529
01:38:33,350 --> 01:38:31,440
it's going to go there's some

2530
01:38:36,530 --> 01:38:33,360
calculations and things

2531
01:38:37,790 --> 01:38:36,540
um and some some examples that I need to

2532
01:38:38,450 --> 01:38:37,800
think through

2533
01:38:40,790 --> 01:38:38,460
um

2534
01:38:42,590 --> 01:38:40,800
eventually that will come out

2535
01:38:45,290 --> 01:38:42,600
there was a phrase that I heard you say

2536
01:38:49,250 --> 01:38:45,300
with Einstein the general view is that

2537
01:38:52,550 --> 01:38:49,260
he spatialized time but instead what we

2538
01:38:54,590 --> 01:38:52,560

should do is temporalize space right

2539
01:38:56,149 --> 01:38:54,600
okay so please expand on that because

2540
01:38:57,410 --> 01:38:56,159
that sounds poetic I don't know what it

2541
01:38:59,890 --> 01:38:57,420
means

2542
01:39:02,330 --> 01:38:59,900
okay so right so

2543
01:39:04,669 --> 01:39:02,340
one thing that people say that is just

2544
01:39:06,729 --> 01:39:04,679
flat incorrect is that in in special

2545
01:39:09,530 --> 01:39:06,739
relativity somehow

2546
01:39:11,570 --> 01:39:09,540
time is just another spatial Dimension

2547
01:39:13,550 --> 01:39:11,580
or that they're placed on equal footing

2548
01:39:15,410 --> 01:39:13,560
they're yeah placed on quote as you say

2549
01:39:17,149 --> 01:39:15,420
equal footing that's just a phrase also

2550
01:39:18,830 --> 01:39:17,159
that that you never hear anywhere else

2551
01:39:19,970 --> 01:39:18,840
except in special relativity so then

2552
01:39:21,229 --> 01:39:19,980
that makes me think that people are just

2553
01:39:23,209 --> 01:39:21,239
copying that phrase because you never

2554
01:39:24,770 --> 01:39:23,219
use the word equal footing in math or

2555
01:39:26,689 --> 01:39:24,780
physics except here when talking about

2556
01:39:27,830 --> 01:39:26,699
space and time everyone repeats it like

2557
01:39:30,530 --> 01:39:27,840
the PowerHouse of the cell is

2558
01:39:32,270 --> 01:39:30,540
mitochondria good good good you you've

2559
01:39:33,770 --> 01:39:32,280
put your finger on something which is

2560
01:39:36,830 --> 01:39:33,780
really smart

2561
01:39:39,470 --> 01:39:36,840
and really perceptive and you should use

2562
01:39:40,970 --> 01:39:39,480
it all the time when a when a whole

2563
01:39:43,729 --> 01:39:40,980

bunch of different people are using

2564
01:39:46,129 --> 01:39:43,739
identically the same language

2565
01:39:47,689 --> 01:39:46,139
it's an indication of a problem

2566
01:39:49,250 --> 01:39:47,699
because if you really understand

2567
01:39:51,470 --> 01:39:49,260
something

2568
01:39:53,209 --> 01:39:51,480
when you speak about it you'll you won't

2569
01:39:54,649 --> 01:39:53,219
always use the same phrases and

2570
01:39:56,689 --> 01:39:54,659
different people will use slightly

2571
01:39:59,390 --> 01:39:56,699
different phrases or you know produce

2572
01:40:01,010 --> 01:39:59,400
different analogies and so on because

2573
01:40:02,629 --> 01:40:01,020
they understand it

2574
01:40:04,729 --> 01:40:02,639
and then they're filtering their

2575
01:40:07,370 --> 01:40:04,739
understanding through language to try

2576
01:40:10,310 --> 01:40:07,380
and convey that understanding when

2577
01:40:12,290 --> 01:40:10,320
everybody's repeating verbatim the same

2578
01:40:15,169 --> 01:40:12,300
phrase they've just memorized that

2579
01:40:17,030 --> 01:40:15,179
phrase right it's an indication of lack

2580
01:40:18,649 --> 01:40:17,040
of really understand I mean look think

2581
01:40:20,510 --> 01:40:18,659
about it I agree wholeheartedly about

2582
01:40:22,970 --> 01:40:20,520
you know think think about the term

2583
01:40:24,890 --> 01:40:22,980
equal footing if by equal footing you

2584
01:40:26,689 --> 01:40:24,900
mean equal then why don't they say as

2585
01:40:29,149 --> 01:40:26,699
they say why don't they say oh he made

2586
01:40:31,010 --> 01:40:29,159
everything into time

2587
01:40:33,530 --> 01:40:31,020
but they say no somehow he made

2588
01:40:36,229 --> 01:40:33,540

everything into space right now we know

2589
01:40:39,110 --> 01:40:36,239
what it would be we know what it is

2590
01:40:40,610 --> 01:40:39,120
to add an extra spatial Dimension so we

2591
01:40:42,530 --> 01:40:40,620
start out thinking space has three

2592
01:40:45,050 --> 01:40:42,540
dimensions you think it might have four

2593
01:40:48,370 --> 01:40:45,060
five we know the tool to represent that

2594
01:40:51,590 --> 01:40:48,380
it's four-dimensional Romanian geometry

2595
01:40:53,810 --> 01:40:51,600
well-defined mathematical subject that's

2596
01:40:57,110 --> 01:40:53,820
not relative

2597
01:40:59,750 --> 01:40:57,120
right the the the the geometry of

2598
01:41:02,810 --> 01:40:59,760
special and general relativity is not

2599
01:41:05,270 --> 01:41:02,820
rimani in Geometry it's lorencian and

2600
01:41:08,510 --> 01:41:05,280
because it's lorencian it contains a

2601
01:41:11,570 --> 01:41:08,520
light cone structure that pseudo purely

2602
01:41:13,669 --> 01:41:11,580
spatial structure has nothing that

2603
01:41:16,790 --> 01:41:13,679
corresponds to a like

2604
01:41:19,490 --> 01:41:16,800
Okay so

2605
01:41:21,350 --> 01:41:19,500
to say they're on equal footing I mean

2606
01:41:23,090 --> 01:41:21,360
again it's kind of also a little vague

2607
01:41:24,890 --> 01:41:23,100
what that means but it certainly doesn't

2608
01:41:26,890 --> 01:41:24,900
mean that you've just turned time into

2609
01:41:28,850 --> 01:41:26,900
space and the real problem of people

2610
01:41:31,729 --> 01:41:28,860
saying that you've turned time into

2611
01:41:34,129 --> 01:41:31,739
space is that space doesn't have a

2612
01:41:36,770 --> 01:41:34,139
directionality

2613
01:41:38,990 --> 01:41:36,780

that is if I were to just go to somebody

2614
01:41:41,149 --> 01:41:39,000
in the street and say you know

2615
01:41:43,729 --> 01:41:41,159
the United States runs from north to

2616
01:41:45,649 --> 01:41:43,739
south and not south to North they'd look

2617
01:41:46,970 --> 01:41:45,659
at me like what in the world are you

2618
01:41:50,090 --> 01:41:46,980
even saying

2619
01:41:52,310 --> 01:41:50,100
right what do you mean

2620
01:41:55,010 --> 01:41:52,320
um there's a north-south dimension if

2621
01:41:57,770 --> 01:41:55,020
you will but it doesn't go one way

2622
01:42:01,370 --> 01:41:57,780
rather than another okay whereas if I

2623
01:42:02,990 --> 01:42:01,380
tell you time goes from past to Future

2624
01:42:04,430 --> 01:42:03,000
and not from the future to the Past

2625
01:42:06,410 --> 01:42:04,440
everybody says yeah of course I mean

2626
01:42:07,729 --> 01:42:06,420
that's a triviality everybody know time

2627
01:42:10,370 --> 01:42:07,739
has a Direction

2628
01:42:13,970 --> 01:42:10,380
everybody we're constantly getting older

2629
01:42:15,410 --> 01:42:13,980
right every you wake up there's some

2630
01:42:16,970 --> 01:42:15,420
that we'll get to that say time is an

2631
01:42:20,209 --> 01:42:16,980
illusion so I'll get your your thoughts

2632
01:42:23,330 --> 01:42:20,219
okay but anyway time intuitively time

2633
01:42:27,350 --> 01:42:23,340
has a direction and space doesn't

2634
01:42:29,990 --> 01:42:27,360
and if if by equal footing

2635
01:42:32,390 --> 01:42:30,000
people took the lesson which many of

2636
01:42:33,950 --> 01:42:32,400
them do is they say oh first of all by

2637
01:42:36,229 --> 01:42:33,960
equal footing you mean you've

2638
01:42:38,510 --> 01:42:36,239

spatialized time somehow time has now

2639
01:42:40,370 --> 01:42:38,520
just become more space but space doesn't

2640
01:42:42,109 --> 01:42:40,380
have a Direction so gee I guess time

2641
01:42:44,930 --> 01:42:42,119
doesn't have a direction now you're in a

2642
01:42:50,930 --> 01:42:47,689
um now when I say you're temporalizing

2643
01:42:54,350 --> 01:42:50,940
space what I mean is something very when

2644
01:42:58,330 --> 01:42:54,360
I said that is something very precise

2645
01:43:02,270 --> 01:42:58,340
take a relativistic space time

2646
01:43:08,629 --> 01:43:05,450
to everything except just the temporal

2647
01:43:09,830 --> 01:43:08,639
structure the proper time structure

2648
01:43:11,570 --> 01:43:09,840
okay

2649
01:43:13,250 --> 01:43:11,580
from that you can recover the whole

2650
01:43:15,649 --> 01:43:13,260
thing okay sorry repeat that one more

2651
01:43:17,750 --> 01:43:15,659
time from the time structure from the

2652
01:43:20,590 --> 01:43:17,760
proper time structure

2653
01:43:23,990 --> 01:43:20,600
you can recover the entire structure

2654
01:43:27,590 --> 01:43:24,000
right information about the the whole

2655
01:43:30,950 --> 01:43:27,600
space-time geometry is contained within

2656
01:43:33,709 --> 01:43:30,960
if you just give me all the causal

2657
01:43:37,910 --> 01:43:33,719
curves all the time like or light-like

2658
01:43:39,770 --> 01:43:37,920
Curves and their proper lengths in right

2659
01:43:42,530 --> 01:43:39,780
in proper time

2660
01:43:44,750 --> 01:43:42,540
that nails down the entire space on

2661
01:43:47,510 --> 01:43:44,760
Geometry

2662
01:43:49,609 --> 01:43:47,520
So to that extent you could say time

2663
01:43:52,669 --> 01:43:49,619

settles everything time has a direction

2664
01:43:55,490 --> 01:43:52,679
we're going to save that yep

2665
01:43:58,310 --> 01:43:55,500
but we agree space doesn't appear to

2666
01:43:59,990 --> 01:43:58,320
have a preferred direction right

2667
01:44:02,090 --> 01:44:00,000
because it doesn't somehow we can

2668
01:44:03,649 --> 01:44:02,100
generate space from a preferred time

2669
01:44:05,930 --> 01:44:03,659
Direction

2670
01:44:07,129 --> 01:44:05,940
you can generate the spatial structure

2671
01:44:10,609 --> 01:44:07,139
yeah

2672
01:44:12,550 --> 01:44:10,619
there's only one special structure

2673
01:44:15,890 --> 01:44:12,560
that's consistent there's only one

2674
01:44:17,870 --> 01:44:15,900
relativistic full relativistic metric

2675
01:44:21,590 --> 01:44:17,880
that's going to be consistent with just

2676
01:44:25,010 --> 01:44:23,689
now is this written somewhere in the

2677
01:44:27,290 --> 01:44:25,020
paper or is this an idea that you're

2678
01:44:28,609 --> 01:44:27,300
twenty look here's what's here here's

2679
01:44:29,930 --> 01:44:28,619
some stuff that's well known it's not

2680
01:44:32,149 --> 01:44:29,940
original to me

2681
01:44:34,250 --> 01:44:32,159
just forget about just give me the light

2682
01:44:37,250 --> 01:44:34,260
cone structure so we all know I hope

2683
01:44:39,649 --> 01:44:37,260
that in a relativistic setting space

2684
01:44:43,550 --> 01:44:39,659
time has a light cone structure so any

2685
01:44:45,129 --> 01:44:43,560
event there's a double cone of right

2686
01:44:48,410 --> 01:44:45,139
cone and a past light

2687
01:44:50,149 --> 01:44:48,420
and let me just comment on that it's

2688
01:44:52,310 --> 01:44:50,159

important that it's a double cone that

2689
01:44:54,950 --> 01:44:52,320
is if I have an arrow pointing into the

2690
01:44:58,550 --> 01:44:54,960
upper part of this of this light

2691
01:45:00,169 --> 01:44:58,560
I can't continuously rotate it down into

2692
01:45:02,270 --> 01:45:00,179
the bottom so it's pointing the other

2693
01:45:04,490 --> 01:45:02,280
direction and always have it Point

2694
01:45:07,370 --> 01:45:04,500
timeline that is have a point within the

2695
01:45:11,209 --> 01:45:07,380
cone the the time like directions are

2696
01:45:12,470 --> 01:45:11,219
divided into two disconnected groups the

2697
01:45:14,689 --> 01:45:12,480
future pointing ones in the past

2698
01:45:16,129 --> 01:45:14,699
pointing ones but the space-like

2699
01:45:17,990 --> 01:45:16,139
directions which are the directions that

2700
01:45:19,970 --> 01:45:18,000
as it were Point outside the light cone

2701
01:45:22,250 --> 01:45:19,980
they're continuously connected I can get

2702
01:45:23,990 --> 01:45:22,260
from any space like direction to any

2703
01:45:27,350 --> 01:45:24,000
other one just always remaining

2704
01:45:29,209 --> 01:45:27,360
spaceline right so that's the sense in

2705
01:45:31,550 --> 01:45:29,219
which time has a direction there's a

2706
01:45:33,229 --> 01:45:31,560
fundamental distinction between the

2707
01:45:35,510 --> 01:45:33,239
future directed

2708
01:45:37,669 --> 01:45:35,520
things and the past directed things and

2709
01:45:38,930 --> 01:45:37,679
there's no corresponding distinction in

2710
01:45:41,270 --> 01:45:38,940
space

2711
01:45:42,950 --> 01:45:41,280
now what's well known is if I just give

2712
01:45:45,649 --> 01:45:42,960
you the light cone structure just the

2713
01:45:48,590 --> 01:45:45,659

light cone structure to specify a

2714
01:45:50,270 --> 01:45:48,600
relativistic metric I need 10 numbers

2715
01:45:53,209 --> 01:45:50,280
if I give you just the light cone

2716
01:45:55,129 --> 01:45:53,219
structure that nails down nine of them

2717
01:45:57,470 --> 01:45:55,139
okay

2718
01:45:59,810 --> 01:45:57,480
that's well known this was proven a long

2719
01:46:01,790 --> 01:45:59,820
time ago so there's just one other

2720
01:46:03,649 --> 01:46:01,800
number that I need and if you give me

2721
01:46:06,649 --> 01:46:03,659
not just the light cone structure but

2722
01:46:08,870 --> 01:46:06,659
the the length the so these time-like

2723
01:46:11,209 --> 01:46:08,880
curves have a length that's called a

2724
01:46:13,550 --> 01:46:11,219
proper time if you tell me that that'll

2725
01:46:15,530 --> 01:46:13,560
nail down the tens number interesting

2726
01:46:17,450 --> 01:46:15,540
done okay there's no other there's no

2727
01:46:19,370 --> 01:46:17,460
other wiggle room you've got everything

2728
01:46:21,530 --> 01:46:19,380
this is well known this is not anything

2729
01:46:23,810 --> 01:46:21,540
special to me

2730
01:46:25,070 --> 01:46:23,820
and so just to be clear when we were

2731
01:46:26,930 --> 01:46:25,080
talking about that if you're in the

2732
01:46:30,050 --> 01:46:26,940
upper part of a light cone then you

2733
01:46:32,209 --> 01:46:30,060
can't go to the bottom part we're in a

2734
01:46:34,669 --> 01:46:32,219
orientable manifold or does this still

2735
01:46:37,070 --> 01:46:34,679
apply and it's always the Assumption

2736
01:46:39,109 --> 01:46:37,080
when you do relativity always always the

2737
01:46:41,870 --> 01:46:39,119
assumption that the manifold is

2738
01:46:43,910 --> 01:46:41,880

temporally orientable so it's not like a

2739
01:46:46,250 --> 01:46:43,920
Mobius strip where you know things get

2740
01:46:47,689 --> 01:46:46,260
twisted up and that's because I missed

2741
01:46:49,189 --> 01:46:47,699
two directions

2742
01:46:50,570 --> 01:46:49,199
I would like to know your thoughts on

2743
01:46:53,570 --> 01:46:50,580
Occam's razor whether it's a good

2744
01:46:55,790 --> 01:46:53,580
principle what are its pros and cons and

2745
01:46:57,229 --> 01:46:55,800
this relates to the manifolds but we'll

2746
01:46:58,669 --> 01:46:57,239
get to that so what are your thoughts

2747
01:47:01,370 --> 01:46:58,679
your what are the pros and cons of

2748
01:47:03,410 --> 01:47:01,380
Occam's razor well again the part of the

2749
01:47:05,930 --> 01:47:03,420
problem is when people use the term

2750
01:47:08,629 --> 01:47:05,940
Occam's razor they often have different

2751
01:47:11,270 --> 01:47:08,639
principles in mind

2752
01:47:16,970 --> 01:47:14,649
so what Occam said was something like

2753
01:47:20,090 --> 01:47:16,980
Anthea nonsense

2754
01:47:23,090 --> 01:47:20,100
uh whatever it is it's in a Prater in

2755
01:47:25,790 --> 01:47:23,100
the quesatum don't postulate entities

2756
01:47:27,649 --> 01:47:25,800
without necessity

2757
01:47:30,410 --> 01:47:27,659
now the problem with that is that what

2758
01:47:32,750 --> 01:47:30,420
do you mean by necessity

2759
01:47:34,490 --> 01:47:32,760
um if if you take that too strongly then

2760
01:47:37,250 --> 01:47:34,500
it's kind of a crazy view because you're

2761
01:47:39,410 --> 01:47:37,260
never really necessitated to postulate

2762
01:47:41,330 --> 01:47:39,420
things so so then you weaken it you say

2763
01:47:44,390 --> 01:47:41,340

look don't postulate entities without

2764
01:47:45,770 --> 01:47:44,400
good reason that that sounds good but

2765
01:47:47,689 --> 01:47:45,780
that's kind of trivial I mean you should

2766
01:47:49,129 --> 01:47:47,699
also not delete entities without good

2767
01:47:50,689 --> 01:47:49,139
reason okay you shouldn't do anything

2768
01:47:53,270 --> 01:47:50,699
without good or you just use good

2769
01:47:55,129 --> 01:47:53,280
reasons okay it becomes good advice but

2770
01:47:57,350 --> 01:47:55,139
kind of trivial

2771
01:48:00,109 --> 01:47:57,360
um yeah sometimes people say well

2772
01:48:01,729 --> 01:48:00,119
Occam's razor says if I have two rival

2773
01:48:05,270 --> 01:48:01,739
theories

2774
01:48:07,270 --> 01:48:05,280
and one postulates fewer things than the

2775
01:48:10,189 --> 01:48:07,280
other so again we go to the idea of

2776
01:48:12,109 --> 01:48:10,199
ontology or beables

2777
01:48:13,729 --> 01:48:12,119
then you should prefer the one with

2778
01:48:16,129 --> 01:48:13,739
fewer

2779
01:48:18,109 --> 01:48:16,139
right some many times people say oh

2780
01:48:20,870 --> 01:48:18,119
that's Occam's race take the one with

2781
01:48:22,370 --> 01:48:20,880
fewer that's certainly not advice that

2782
01:48:25,090 --> 01:48:22,380
physicists follow and I think for good

2783
01:48:27,310 --> 01:48:25,100
reason why for example take a classical

2784
01:48:30,950 --> 01:48:27,320
electromagnetic Theory

2785
01:48:33,470 --> 01:48:30,960
of the sort that that Max welded

2786
01:48:35,090 --> 01:48:33,480
so it's got charged particles that's

2787
01:48:36,890 --> 01:48:35,100
part of the ontology

2788
01:48:38,750 --> 01:48:36,900

and it's got Fields it's got

2789
01:48:41,030 --> 01:48:38,760
electromagnetic fields

2790
01:48:42,770 --> 01:48:41,040
now you can imagine a theory that gets

2791
01:48:44,510 --> 01:48:42,780
rid of the fields and a kind of action

2792
01:48:46,490 --> 01:48:44,520
at a distance Theory this is what we'll

2793
01:48:48,770 --> 01:48:46,500
learn fine when we're doing you just

2794
01:48:51,189 --> 01:48:48,780
throw away the fields and you say no no

2795
01:48:54,770 --> 01:48:51,199
it's not that discharged particle

2796
01:48:56,629 --> 01:48:54,780
affects that one by the effect of an

2797
01:48:59,870 --> 01:48:56,639
intermediate field it's that this one is

2798
01:49:02,689 --> 01:48:59,880
directly affects that one maybe with a

2799
01:49:05,390 --> 01:49:02,699
time lag with nothing between them well

2800
01:49:07,669 --> 01:49:05,400
clearly that second theory has less

2801
01:49:09,350 --> 01:49:07,679
ontology than the first one because it's

2802
01:49:10,609 --> 01:49:09,360
you know they both have the particles

2803
01:49:11,990 --> 01:49:10,619
and one has the fields in the other

2804
01:49:14,330 --> 01:49:12,000
doesn't doesn't mean it's a better

2805
01:49:17,709 --> 01:49:14,340
theory in fact it it seems like a much

2806
01:49:21,109 --> 01:49:17,719
worse Theory because you give up certain

2807
01:49:25,070 --> 01:49:21,119
principles of continuous action and so

2808
01:49:26,930 --> 01:49:25,080
on in in favor of this you know spooky

2809
01:49:28,790 --> 01:49:26,940
action at a distance or whatever

2810
01:49:30,770 --> 01:49:28,800
um I mean no physicists took that very

2811
01:49:33,169 --> 01:49:30,780
would take that seriously they'd say

2812
01:49:34,970 --> 01:49:33,179
look wait I but I have a whole set of

2813
01:49:36,709 --> 01:49:34,980

equations for the electric and magnetic

2814
01:49:39,649 --> 01:49:36,719
fields I understand how they behave I

2815
01:49:41,390 --> 01:49:39,659
understand how jiggling this charged

2816
01:49:43,669 --> 01:49:41,400
particle creates an electromagnetic

2817
01:49:45,649 --> 01:49:43,679
field that goes through space and time

2818
01:49:47,390 --> 01:49:45,659
and then hits this charge particle in an

2819
01:49:50,390 --> 01:49:47,400
antenna and makes it go up and down and

2820
01:49:52,729 --> 01:49:50,400
then I turn on my radio okay and if

2821
01:49:55,250 --> 01:49:52,739
somebody wants to explain that taking

2822
01:49:57,050 --> 01:49:55,260
away the intermediary Fields that's just

2823
01:49:58,310 --> 01:49:57,060
a very strange thing to do I certainly

2824
01:50:01,310 --> 01:49:58,320
shouldn't think

2825
01:50:03,530 --> 01:50:01,320
that you know less is more

2826
01:50:05,109 --> 01:50:03,540
in ontology

2827
01:50:08,629 --> 01:50:05,119
so

2828
01:50:10,370 --> 01:50:08,639
again if it's just if the advice is look

2829
01:50:12,590 --> 01:50:10,380
just think about the ontology when

2830
01:50:16,070 --> 01:50:12,600
you're comparing two theories

2831
01:50:18,109 --> 01:50:16,080
compare their ontology and ask what is

2832
01:50:20,209 --> 01:50:18,119
the justification

2833
01:50:22,669 --> 01:50:20,219
where one has more

2834
01:50:24,410 --> 01:50:22,679
if one strictly has more what's the

2835
01:50:26,090 --> 01:50:24,420
justification think about that

2836
01:50:27,890 --> 01:50:26,100
justification that's good advice but

2837
01:50:29,750 --> 01:50:27,900
it's not good advice to say no don't

2838
01:50:33,050 --> 01:50:29,760

even think about that just just compare

2839
01:50:35,330 --> 01:50:33,060
them and then and and announce that the

2840
01:50:36,709 --> 01:50:35,340
one with less ontology is better

2841
01:50:39,770 --> 01:50:36,719
because you don't you have to think

2842
01:50:42,109 --> 01:50:39,780
about what price you're paying yeah get

2843
01:50:44,629 --> 01:50:42,119
rid of it with the Feynman case with

2844
01:50:46,930 --> 01:50:44,639
wheeler was their mathematical treatment

2845
01:50:49,189 --> 01:50:46,940
more complex than the original

2846
01:50:51,410 --> 01:50:49,199
electromagnetic from oh yeah because

2847
01:50:53,030 --> 01:50:51,420
because the the wheeler Feynman Theory

2848
01:50:55,250 --> 01:50:53,040
tried to get rid of the electromagnetic

2849
01:50:57,530 --> 01:50:55,260
fields in favor of and now this comes

2850
01:51:01,490 --> 01:50:57,540
back to the stuff about retro causation

2851
01:51:04,370 --> 01:51:01,500
in favor of having direct action at a

2852
01:51:07,669 --> 01:51:04,380
distance both to the past and to the

2853
01:51:11,510 --> 01:51:07,679
Future so what what the way a particle

2854
01:51:14,209 --> 01:51:11,520
charged particle behaves right now

2855
01:51:16,790 --> 01:51:14,219
was determined by looking both on its

2856
01:51:18,470 --> 01:51:16,800
past light cone and seeing where there

2857
01:51:20,990 --> 01:51:18,480
are other charged particles on the past

2858
01:51:22,669 --> 01:51:21,000
light cone and what they're doing and on

2859
01:51:24,109 --> 01:51:22,679
the future right cone and where there

2860
01:51:26,090 --> 01:51:24,119
are other particles on the future of

2861
01:51:28,669 --> 01:51:26,100
Icon and what they're doing

2862
01:51:30,590 --> 01:51:28,679
and so you had instead of what we

2863
01:51:33,590 --> 01:51:30,600

normally have which is a boundary

2864
01:51:35,689 --> 01:51:33,600
condition a single boundary condition

2865
01:51:37,370 --> 01:51:35,699
from which you generate the future in

2866
01:51:39,050 --> 01:51:37,380
the past you had a boundary condition to

2867
01:51:40,669 --> 01:51:39,060
the past and a boundary condition to the

2868
01:51:41,990 --> 01:51:40,679
Future and to the Future they use this

2869
01:51:43,970 --> 01:51:42,000
thing called an absorber a perfect

2870
01:51:45,590 --> 01:51:43,980
absorber condition blah blah blah but

2871
01:51:47,030 --> 01:51:45,600
just mathematically that's a much more

2872
01:51:50,629 --> 01:51:47,040
difficult problem

2873
01:51:53,930 --> 01:51:50,639
can write down some equations to know

2874
01:51:55,970 --> 01:51:53,940
whether they even have any solutions

2875
01:51:57,890 --> 01:51:55,980
it's just mathematically all very

2876
01:52:01,970 --> 01:51:57,900
intractable

2877
01:52:04,310 --> 01:52:01,980
means that they weren't able to produce

2878
01:52:05,750 --> 01:52:04,320
or reproduce the results yeah as far as

2879
01:52:07,810 --> 01:52:05,760
I know I mean I know knew some people

2880
01:52:11,390 --> 01:52:07,820
who were interested in this Theory

2881
01:52:13,790 --> 01:52:11,400
uh in Munich and you know recent I mean

2882
01:52:16,370 --> 01:52:13,800
within the last 20 years and we're

2883
01:52:18,530 --> 01:52:16,380
working on it and to my knowledge they

2884
01:52:20,330 --> 01:52:18,540
never exactly got a precise solution

2885
01:52:22,129 --> 01:52:20,340
either but I haven't looked at it in

2886
01:52:24,950 --> 01:52:22,139
much detail it's coming it's just clear

2887
01:52:26,450 --> 01:52:24,960
on mathematical grounds

2888
01:52:27,950 --> 01:52:26,460

when you have something like Newton's

2889
01:52:29,990 --> 01:52:27,960
equations

2890
01:52:31,669 --> 01:52:30,000
if you give me an initial condition and

2891
01:52:33,530 --> 01:52:31,679
tell me the positions and moment of all

2892
01:52:36,410 --> 01:52:33,540
the particles

2893
01:52:38,450 --> 01:52:36,420
then there then you can prove in certain

2894
01:52:40,129 --> 01:52:38,460
circumstances there's a unique solution

2895
01:52:42,050 --> 01:52:40,139
to the Future there's a unique solution

2896
01:52:44,810 --> 01:52:42,060
to the past and you can actually get

2897
01:52:47,090 --> 01:52:44,820
your hands on it right mathematically

2898
01:52:48,530 --> 01:52:47,100
but when you say no now I have a

2899
01:52:50,629 --> 01:52:48,540
situation where I have one boundary

2900
01:52:52,250 --> 01:52:50,639
condition to the past and one boundary

2901
01:52:55,669 --> 01:52:52,260
condition to the future and I'm trying

2902
01:52:57,950 --> 01:52:55,679
to solve in between

2903
01:53:00,109 --> 01:52:57,960
it just mathematically I mean you can

2904
01:53:02,570 --> 01:53:00,119
imagine how do you go about it I mean in

2905
01:53:05,030 --> 01:53:02,580
the case of Newton literally you imagine

2906
01:53:06,649 --> 01:53:05,040
on a computer you set some data here and

2907
01:53:07,790 --> 01:53:06,659
then the computer computes okay then a

2908
01:53:10,129 --> 01:53:07,800
little later this then a little later

2909
01:53:11,510 --> 01:53:10,139
this then it just builds it up or a

2910
01:53:14,090 --> 01:53:11,520
little earlier this a little early

2911
01:53:18,169 --> 01:53:14,100
builds it down but if I if I give you

2912
01:53:20,090 --> 01:53:18,179
data here and here and I have to somehow

2913
01:53:22,490 --> 01:53:20,100

fill in the middle in a way that's

2914
01:53:25,370 --> 01:53:22,500
consistent with it it's not even quite

2915
01:53:27,109 --> 01:53:25,380
clear how you proceed if wheeler and

2916
01:53:28,430 --> 01:53:27,119
Feynman were able to reproduce it you

2917
01:53:30,890 --> 01:53:28,440
would still have the same objection it's

2918
01:53:34,189 --> 01:53:30,900
complex I I'm not sure I mean you would

2919
01:53:36,109 --> 01:53:34,199
really have to ask yourself look if the

2920
01:53:37,430 --> 01:53:36,119
theory that postulates electromagnetic

2921
01:53:40,310 --> 01:53:37,440
fields

2922
01:53:42,169 --> 01:53:40,320
has this simple Newtonian presentation

2923
01:53:44,450 --> 01:53:42,179
which it does

2924
01:53:47,209 --> 01:53:44,460
right I just do an initial Simplicity

2925
01:53:48,950 --> 01:53:47,219
needs to factor in two so sorry I don't

2926
01:53:51,109 --> 01:53:48,960
mean to interrupt I apologize so

2927
01:53:52,850 --> 01:53:51,119
Simplicity has to factor in as well it's

2928
01:53:54,590 --> 01:53:52,860
not just less assumptions is there

2929
01:53:56,209 --> 01:53:54,600
another quality like Aesthetics is there

2930
01:53:58,669 --> 01:53:56,219
like what are the factors that need to

2931
01:54:00,050 --> 01:53:58,679
be in place because Occam's it's the way

2932
01:54:01,550 --> 01:54:00,060
it's ordinarily state is you have

2933
01:54:03,649 --> 01:54:01,560
competing theories which everyone has

2934
01:54:06,410 --> 01:54:03,659
less assumptions but produces the same

2935
01:54:08,990 --> 01:54:06,420
results you choose that one yeah I mean

2936
01:54:12,709 --> 01:54:09,000
I I again

2937
01:54:14,030 --> 01:54:12,719
even the if you're a magician if you're

2938
01:54:15,590 --> 01:54:14,040

like a philosopher and you're used to

2939
01:54:17,330 --> 01:54:15,600
these logical tricks you say well what

2940
01:54:18,950 --> 01:54:17,340
do you mean fewer assumptions if if I

2941
01:54:20,629 --> 01:54:18,960
have a theory with 10 assumptions then I

2942
01:54:22,310 --> 01:54:20,639
just put a conjunction between them and

2943
01:54:24,709 --> 01:54:22,320
I have a single sentence that's where I

2944
01:54:26,750 --> 01:54:24,719
was getting at well that's my objection

2945
01:54:28,790 --> 01:54:26,760
with Occam's razor it's all it's to me

2946
01:54:30,050 --> 01:54:28,800
it's unclear what counts as an

2947
01:54:31,850 --> 01:54:30,060
assumption so some people say the

2948
01:54:34,129 --> 01:54:31,860
simplest is God did it but I don't know

2949
01:54:36,470 --> 01:54:34,139
if God is one assumption or if it's ten

2950
01:54:38,570 --> 01:54:36,480
I just pause it space time is that one

2951
01:54:40,729 --> 01:54:38,580
assumption space-time has a huge

2952
01:54:42,830 --> 01:54:40,739
structure so it's like a manifold is

2953
01:54:44,149 --> 01:54:42,840
like second countable hawsdorf and then

2954
01:54:46,850 --> 01:54:44,159
there's atlases and then there's

2955
01:54:49,970 --> 01:54:46,860
orientations so is that one assumption

2956
01:54:51,770 --> 01:54:49,980
yeah and I I think quite honestly it's a

2957
01:54:53,990 --> 01:54:51,780
Fool's errand to think that you can come

2958
01:54:56,570 --> 01:54:54,000
up with some abstract statement of a

2959
01:54:58,729 --> 01:54:56,580
methodological principle that'll be the

2960
01:55:01,729 --> 01:54:58,739
right one to apply in all cases I mean

2961
01:55:04,250 --> 01:55:01,739
start with the problem in front of you

2962
01:55:06,590 --> 01:55:04,260
the problem in front of you is going to

2963
01:55:07,669 --> 01:55:06,600

be here's one Theory here's another

2964
01:55:10,669 --> 01:55:07,679
theory

2965
01:55:12,649 --> 01:55:10,679
and let's assume that they make the same

2966
01:55:14,450 --> 01:55:12,659
empirical predictions or where they

2967
01:55:16,189 --> 01:55:14,460
differ you can't check or something so

2968
01:55:17,810 --> 01:55:16,199
you can't say I'm just going to do an

2969
01:55:19,070 --> 01:55:17,820
experiment to try and decide between

2970
01:55:21,609 --> 01:55:19,080
them

2971
01:55:24,470 --> 01:55:21,619
then people will will start producing

2972
01:55:26,689 --> 01:55:24,480
justifications for taking thinking one

2973
01:55:29,570 --> 01:55:26,699
is more plausible than the other

2974
01:55:32,270 --> 01:55:29,580
and your job is to think through those

2975
01:55:35,930 --> 01:55:32,280
justifications now I I don't think any

2976
01:55:37,729 --> 01:55:35,940
you know single sentence in Latin is

2977
01:55:41,810 --> 01:55:37,739
going to give you very helpful advice

2978
01:55:43,970 --> 01:55:41,820
Universal advice about how to do that

2979
01:55:46,250 --> 01:55:43,980
um it might be that in some sense one of

2980
01:55:50,149 --> 01:55:46,260
the theories is simpler is is clearly

2981
01:55:52,250 --> 01:55:50,159
simpler than the other with no penalty

2982
01:55:54,890 --> 01:55:52,260
then you'd say okay the simpler one just

2983
01:55:56,330 --> 01:55:54,900
seems more plausible but usually there

2984
01:55:58,430 --> 01:55:56,340
are trade-offs

2985
01:56:00,350 --> 01:55:58,440
how important are they how much of this

2986
01:56:01,430 --> 01:56:00,360
will you give up for that there's no

2987
01:56:04,790 --> 01:56:01,440
going to be not going to be a general

2988
01:56:07,609 --> 01:56:04,800

calculus of this you should just try to

2989
01:56:08,810 --> 01:56:07,619
be as explicit as you can in the

2990
01:56:10,669 --> 01:56:08,820
accounting

2991
01:56:13,729 --> 01:56:10,679
right so you say here's Theory one

2992
01:56:15,770 --> 01:56:13,739
here's its ontology here its laws here's

2993
01:56:17,149 --> 01:56:15,780
Theory two here's its ontology here's

2994
01:56:17,870 --> 01:56:17,159
its laws

2995
01:56:22,010 --> 01:56:17,880
um

2996
01:56:24,770 --> 01:56:22,020
if I prefer if if on grounds other than

2997
01:56:27,590 --> 01:56:24,780
empirical grounds I prefer a to B let me

2998
01:56:29,810 --> 01:56:27,600
say why and then just listen right I

2999
01:56:31,910 --> 01:56:29,820
mean you know and the kind of the kind

3000
01:56:34,669 --> 01:56:31,920
of justification you might get may be

3001
01:56:36,709 --> 01:56:34,679
very specific to the particular

3002
01:56:40,250 --> 01:56:36,719
mathematics being used I mean God knows

3003
01:56:43,129 --> 01:56:40,260
what I mean don't don't expect some guy

3004
01:56:44,930 --> 01:56:43,139
you know in the Middle Ages wrote down

3005
01:56:47,030 --> 01:56:44,940
something that is going to give you the

3006
01:56:49,010 --> 01:56:47,040
Royal Key to deciding between these

3007
01:56:51,709 --> 01:56:49,020
things and maybe there's no good way to

3008
01:56:53,570 --> 01:56:51,719
decide between them I mean we should be

3009
01:56:56,870 --> 01:56:53,580
prepared

3010
01:56:58,970 --> 01:56:56,880
to have alternative physical accounts of

3011
01:57:00,830 --> 01:56:58,980
the world that we don't actually have

3012
01:57:02,330 --> 01:57:00,840
any particularly good reason to decide

3013
01:57:04,850 --> 01:57:02,340

between and if that's the situation

3014
01:57:06,590 --> 01:57:04,860
that's the situation

3015
01:57:08,870 --> 01:57:06,600
you know

3016
01:57:11,750 --> 01:57:08,880
speaking of what's what's tricky to

3017
01:57:13,850 --> 01:57:11,760
decide between the illusion of time so

3018
01:57:15,709 --> 01:57:13,860
there are certain theories in well

3019
01:57:19,370 --> 01:57:15,719
there's certain interpretations of time

3020
01:57:21,770 --> 01:57:19,380
such as Carlo rivelli's there's Julian

3021
01:57:23,570 --> 01:57:21,780
Barbers we'll get to them what does the

3022
01:57:25,570 --> 01:57:23,580
PBR theorem have to say about relational

3023
01:57:29,149 --> 01:57:25,580
quantum mechanics

3024
01:57:30,589 --> 01:57:29,159
yeah so so yeah you you did give me some

3025
01:57:33,229 --> 01:57:30,599
warning you were going to ask that

3026
01:57:35,629 --> 01:57:33,239
question and and I I afraid I just have

3027
01:57:37,370 --> 01:57:35,639
to say I don't understand relational

3028
01:57:39,589 --> 01:57:37,380
quantum mechanics I've looked at it a

3029
01:57:41,330 --> 01:57:39,599
bit I talked to Carl about it a bit I

3030
01:57:43,250 --> 01:57:41,340
just don't understand it

3031
01:57:45,709 --> 01:57:43,260
uh I know some people who've looked at

3032
01:57:48,109 --> 01:57:45,719
it more carefully and they were unable

3033
01:57:50,390 --> 01:57:48,119
to find what they considered a coherent

3034
01:57:53,030 --> 01:57:50,400
formulation of it

3035
01:57:55,850 --> 01:57:53,040
um if you feel like you understand it

3036
01:57:57,950 --> 01:57:55,860
then you can explain it to me and I can

3037
01:57:59,570 --> 01:57:57,960
try to respond if you feel like you

3038
01:58:01,490 --> 01:57:59,580

don't really understand it and can just

3039
01:58:02,330 --> 01:58:01,500
repeat what other people say we're a bit

3040
01:58:04,970 --> 01:58:02,340
stuck

3041
01:58:08,149 --> 01:58:04,980
uh I just I just don't understand what

3042
01:58:11,390 --> 01:58:08,159
the theory claims even apart from time

3043
01:58:14,750 --> 01:58:11,400
and then my issue here isn't about time

3044
01:58:17,330 --> 01:58:14,760
um I I don't understand what it means to

3045
01:58:19,850 --> 01:58:17,340
say that all that's real are relations

3046
01:58:21,470 --> 01:58:19,860
it's I mean sometimes there's this tag

3047
01:58:23,270 --> 01:58:21,480
phrase that people say oh relations

3048
01:58:25,310 --> 01:58:23,280
without rolata

3049
01:58:26,570 --> 01:58:25,320
and this is you know you're just

3050
01:58:28,669 --> 01:58:26,580
contradicting how can you have a

3051
01:58:30,470 --> 01:58:28,679
relation without Roboto or

3052
01:58:31,850 --> 01:58:30,480
um things only exist when they interact

3053
01:58:33,229 --> 01:58:31,860
and then you want to say but wait if

3054
01:58:36,109 --> 01:58:33,239
they weren't already there how could

3055
01:58:37,970 --> 01:58:36,119
they interact I mean how can how can

3056
01:58:40,609 --> 01:58:37,980
interaction occur between two things

3057
01:58:42,950 --> 01:58:40,619
that don't exist

3058
01:58:46,189 --> 01:58:42,960
um I I don't I literally don't

3059
01:58:48,950 --> 01:58:46,199
understand what's being claimed

3060
01:58:50,450 --> 01:58:48,960
um I once I mean I can uh if and again

3061
01:58:53,570 --> 01:58:50,460
if you feel like you want to explain it

3062
01:58:56,750 --> 01:58:53,580
to me I'm I'm all ears I I will again

3063
01:58:58,430 --> 01:58:56,760

one one little data point was was once I

3064
01:59:00,530 --> 01:58:58,440
was puzzled about stuff talking to Carl

3065
01:59:02,629 --> 01:59:00,540
and we were talking about non-locality

3066
01:59:04,070 --> 01:59:02,639
right so in the non-locality case Alice

3067
01:59:07,550 --> 01:59:04,080
does an experiment over here and Bob

3068
01:59:10,910 --> 01:59:07,560
does an experiment very far away and the

3069
01:59:13,010 --> 01:59:10,920
issue is the correlations between the

3070
01:59:15,550 --> 01:59:13,020
outcomes of the experiments they do

3071
01:59:17,570 --> 01:59:15,560
right that that's what Bell's inequality

3072
01:59:19,750 --> 01:59:17,580
puts constraints on on these

3073
01:59:23,830 --> 01:59:19,760
correlations

3074
01:59:29,510 --> 01:59:26,450
as far as I could understood Carlos

3075
01:59:33,790 --> 01:59:29,520
seemed to be saying that that

3076
01:59:36,890 --> 01:59:33,800
uh there is no outcome for Bob

3077
01:59:38,870 --> 01:59:36,900
just you can't just talk about what

3078
01:59:40,490 --> 01:59:38,880
happened in Bob's lab right you normally

3079
01:59:42,470 --> 01:59:40,500
think you could you say okay Bob did an

3080
01:59:44,570 --> 01:59:42,480
experiment did he get a DOT here or a

3081
01:59:47,510 --> 01:59:44,580
DOT there you know was it an up or down

3082
01:59:50,870 --> 01:59:47,520
outcome and it's like no no no he only

3083
01:59:54,350 --> 01:59:50,880
had an outcome relative to Alice and

3084
01:59:57,050 --> 01:59:54,360
furthermore somehow that outcome only

3085
01:59:59,330 --> 01:59:57,060
occurs when Alice and Bob interact and

3086
02:00:01,129 --> 01:59:59,340
Allison Bob only interact when after the

3087
02:00:03,109 --> 02:00:01,139
experiment they come back together and

3088
02:00:05,030 --> 02:00:03,119

share data or something like that

3089
02:00:06,890 --> 02:00:05,040
and and I said don't understand Carlos

3090
02:00:09,350 --> 02:00:06,900
so if I'm Bob

3091
02:00:11,649 --> 02:00:09,360
and I do my experiment right and I have

3092
02:00:14,330 --> 02:00:11,659
my data and then I'm waiting for Alice

3093
02:00:16,729 --> 02:00:14,340
Alice's to come meet me to share her

3094
02:00:18,770 --> 02:00:16,739
data and Alice comes and she says you

3095
02:00:19,910 --> 02:00:18,780
know uh 10 minutes ago I just got this

3096
02:00:22,669 --> 02:00:19,920
result

3097
02:00:24,530 --> 02:00:22,679
do I not believe her

3098
02:00:27,050 --> 02:00:24,540
I mean do I literally just not believe

3099
02:00:29,270 --> 02:00:27,060
yes you got that result 15 minutes ago

3100
02:00:31,790 --> 02:00:29,280
long before I ever found out about it

3101
02:00:34,490 --> 02:00:31,800
and long before we ever interacted

3102
02:00:36,050 --> 02:00:34,500
and and Carl just looked at me like I'd

3103
02:00:38,209 --> 02:00:36,060
asked a question that never occurred to

3104
02:00:40,070 --> 02:00:38,219
him I mean he didn't have a ready answer

3105
02:00:41,930 --> 02:00:40,080
at the time I don't know if he does now

3106
02:00:44,629 --> 02:00:41,940
and at that point I just don't

3107
02:00:46,189 --> 02:00:44,639
understand I mean I think Alice is there

3108
02:00:47,870 --> 02:00:46,199
doing her experiments and getting her

3109
02:00:49,490 --> 02:00:47,880
outcomes and Bob is there doing his

3110
02:00:51,770 --> 02:00:49,500
experiments and getting his outcomes

3111
02:00:53,689 --> 02:00:51,780
quite even though they're not

3112
02:00:57,350 --> 02:00:53,699
interacting with each other

3113
02:00:58,970 --> 02:00:57,360

in a normal sense of interaction

3114
02:01:00,890 --> 02:00:58,980
um

3115
02:01:02,750 --> 02:01:00,900
and those outcomes are what they are and

3116
02:01:04,430 --> 02:01:02,760
they do or they do not violate Bell's

3117
02:01:06,530 --> 02:01:04,440
inequality

3118
02:01:09,470 --> 02:01:06,540
I don't understand what the relational

3119
02:01:12,530 --> 02:01:09,480
Theory says about that case I have some

3120
02:01:14,689 --> 02:01:12,540
puzzlement because I asked Carlo well

3121
02:01:16,430 --> 02:01:14,699
what's being related and then I believe

3122
02:01:18,410 --> 02:01:16,440
he said certain relations then I said

3123
02:01:19,850 --> 02:01:18,420
well what are those relating and is it

3124
02:01:24,010 --> 02:01:19,860
not just some infinite regress of

3125
02:01:28,729 --> 02:01:24,020
relations and then he said yes

3126
02:01:34,490 --> 02:01:32,149
but look this is I mean saying yes is

3127
02:01:37,250 --> 02:01:34,500
very is is maybe it's honest it's kind

3128
02:01:40,250 --> 02:01:37,260
of fun I mean there's a Dr Seuss story

3129
02:01:43,790 --> 02:01:40,260
about the about about the lazy bees in

3130
02:01:45,410 --> 02:01:43,800
Hotshot right so um so you know they

3131
02:01:47,450 --> 02:01:45,420
they find that when the bee Watcher

3132
02:01:49,609 --> 02:01:47,460
watches the bees they're they're busier

3133
02:01:51,770 --> 02:01:49,619
so they hire a b Watcher but the B

3134
02:01:54,290 --> 02:01:51,780
Watcher was lazy so they had to hire a b

3135
02:01:56,330 --> 02:01:54,300
Watcher Watcher and then if you watch or

3136
02:01:57,109 --> 02:01:56,340
watch her to watch The Bee Watcher and

3137
02:01:58,370 --> 02:01:57,119
and

3138
02:02:00,890 --> 02:01:58,380

um you know it's the same thing people

3139
02:02:02,750 --> 02:02:00,900
say well you know reality doesn't exist

3140
02:02:04,129 --> 02:02:02,760
until an observer observes something and

3141
02:02:05,390 --> 02:02:04,139
you say but wait did The Observer

3142
02:02:07,609 --> 02:02:05,400
already exist

3143
02:02:09,050 --> 02:02:07,619
oh no no The Observer only exists

3144
02:02:10,910 --> 02:02:09,060
because some super Observer was

3145
02:02:12,709 --> 02:02:10,920
observing The Observer but did the super

3146
02:02:14,330 --> 02:02:12,719
Observer already exist oh no there had

3147
02:02:16,070 --> 02:02:14,340
to be a super super Observer and then

3148
02:02:17,810 --> 02:02:16,080
you said this is just silly I mean you

3149
02:02:19,430 --> 02:02:17,820
know why are you doing this and if

3150
02:02:20,810 --> 02:02:19,440
someone said well is it Turtles all the

3151
02:02:22,609 --> 02:02:20,820
way down yes they're an infinite there's

3152
02:02:24,229 --> 02:02:22,619
an infinite hierarchy of observers

3153
02:02:26,209 --> 02:02:24,239
observing other observers bringing them

3154
02:02:27,589 --> 02:02:26,219
into existence you just say look you can

3155
02:02:29,570 --> 02:02:27,599
say this stuff

3156
02:02:31,070 --> 02:02:29,580
but why are you doing it I mean we've

3157
02:02:32,629 --> 02:02:31,080
perfectly good accounts of the physics

3158
02:02:34,910 --> 02:02:32,639
here that don't involve this kind of

3159
02:02:37,189 --> 02:02:34,920
ridiculous gymnastics

3160
02:02:40,129 --> 02:02:37,199
what's motivating you to say things like

3161
02:02:43,010 --> 02:02:40,139
that yeah so the way that I view it and

3162
02:02:46,430 --> 02:02:43,020
again just so we're clear Carlo another

3163
02:02:47,990 --> 02:02:46,440

a huge admiration for Carlo huge

3164
02:02:50,270 --> 02:02:48,000
intellectual giant so I'm Switzerland

3165
02:02:53,570 --> 02:02:50,280
when it comes to this I think that many

3166
02:02:55,490 --> 02:02:53,580
people they believe that and I'm not

3167
02:02:57,050 --> 02:02:55,500
categorizing Carlos this I'm referring

3168
02:02:59,570 --> 02:02:57,060
to those people about The Observers and

3169
02:03:02,330 --> 02:02:59,580
infinite regress of super observersal

3170
02:03:03,649 --> 02:03:02,340
not regress but superset yeah I think

3171
02:03:05,810 --> 02:03:03,659
that people

3172
02:03:08,270 --> 02:03:05,820
including myself including everyone I

3173
02:03:09,589 --> 02:03:08,280
think that people reason backward and we

3174
02:03:11,689 --> 02:03:09,599
believe that we're reasoning from found

3175
02:03:13,729 --> 02:03:11,699
it we say first principles almost no one

3176
02:03:15,050 --> 02:03:13,739
is a first principles thinker we have

3177
02:03:17,089 --> 02:03:15,060
certain values that we're trying to

3178
02:03:20,149 --> 02:03:17,099
preserve and we reason backward and we

3179
02:03:23,209 --> 02:03:20,159
say well you know how a implies B is the

3180
02:03:24,709 --> 02:03:23,219
exact same as not B implies not a let me

3181
02:03:28,430 --> 02:03:24,719
give you a story

3182
02:03:30,830 --> 02:03:28,440
I was driving with someone who is of

3183
02:03:32,030 --> 02:03:30,840
extremely liberal temperament and I'm

3184
02:03:33,589 --> 02:03:32,040
not there's nothing wrong with that and

3185
02:03:35,629 --> 02:03:33,599
I said oh that dog breed is known for

3186
02:03:36,770 --> 02:03:35,639
being extremely intelligent then she's

3187
02:03:38,089 --> 02:03:36,780
like no

3188
02:03:40,010 --> 02:03:38,099

I'm like what do you mean no it's just

3189
02:03:42,109 --> 02:03:40,020
known for being Intel it has a higher IQ

3190
02:03:44,750 --> 02:03:42,119
she's like what what are you talking

3191
02:03:46,609 --> 02:03:44,760
about higher IQ in in dogs and then I

3192
02:03:48,470 --> 02:03:46,619
realized what's happening is that she

3193
02:03:50,750 --> 02:03:48,480
believed that what could be done is I

3194
02:03:52,609 --> 02:03:50,760
could then infer onto humans and say oh

3195
02:03:55,129 --> 02:03:52,619
well there are different species here so

3196
02:03:57,649 --> 02:03:55,139
because that is not she wants to

3197
02:03:59,030 --> 02:03:57,659
preserve that she reasons backward okay

3198
02:04:01,490 --> 02:03:59,040
so I believe that that's what's

3199
02:04:03,229 --> 02:04:01,500
occurring in many of these cases well I

3200
02:04:05,930 --> 02:04:03,239
look there there's a there's a tradition

3201
02:04:08,209 --> 02:04:05,940
there's a tradition going back to bore

3202
02:04:10,310 --> 02:04:08,219
and it's kind of associated with the

3203
02:04:12,649 --> 02:04:10,320
Copenhagen school or the Copenhagen

3204
02:04:13,490 --> 02:04:12,659
Spirit or whatever

3205
02:04:15,709 --> 02:04:13,500
um

3206
02:04:18,050 --> 02:04:15,719
that thinks that the the great

3207
02:04:20,390 --> 02:04:18,060
revolution in quantum theory is because

3208
02:04:22,729 --> 02:04:20,400
the Observer unlike In classical physics

3209
02:04:25,010 --> 02:04:22,739
unlike in Newtonian physics

3210
02:04:26,450 --> 02:04:25,020
The Observer somehow plays a central

3211
02:04:28,550 --> 02:04:26,460
role

3212
02:04:33,010 --> 02:04:28,560
in quantum theory

3213
02:04:35,570 --> 02:04:33,020

and uh the problem is that on no actual

3214
02:04:37,910 --> 02:04:35,580
existing precise understanding of

3215
02:04:39,950 --> 02:04:37,920
quantum theory that we have is that true

3216
02:04:42,589 --> 02:04:39,960
it's just there I mean for many years

3217
02:04:44,450 --> 02:04:42,599
for decades there's been a intermittent

3218
02:04:46,010 --> 02:04:44,460
series of meetings and the title of the

3219
02:04:49,510 --> 02:04:46,020
meetings is quantum theory without the

3220
02:04:52,370 --> 02:04:49,520
Observer and it's just

3221
02:04:54,370 --> 02:04:52,380
formulations uh theories that would

3222
02:04:56,990 --> 02:04:54,380
would account for the quantum phenomena

3223
02:04:58,970 --> 02:04:57,000
uh where in their formulation they never

3224
02:05:01,729 --> 02:04:58,980
mentioned observers and and there's a

3225
02:05:04,609 --> 02:05:01,739
wonderful phrase that Bell has at one

3226
02:05:07,430 --> 02:05:04,619
point he says this is a theory that is

3227
02:05:10,129 --> 02:05:07,440
neither requires nor is embarrassed by

3228
02:05:11,689 --> 02:05:10,139
the existence that are Observer right I

3229
02:05:14,089 --> 02:05:11,699
mean it's not that the physics is going

3230
02:05:17,270 --> 02:05:14,099
to have trouble modeling observers their

3231
02:05:20,089 --> 02:05:17,280
physical systems but gee you know I I

3232
02:05:21,770 --> 02:05:20,099
mean we all think don't we that shortly

3233
02:05:23,810 --> 02:05:21,780
after the big bang a whole bunch of

3234
02:05:25,609 --> 02:05:23,820
physical stuff happened and there was

3235
02:05:28,189 --> 02:05:25,619
nobody there observing it

3236
02:05:31,850 --> 02:05:28,199
I mean it's kind of again you you kind

3237
02:05:34,669 --> 02:05:31,860
of blows your mind when you try and see

3238
02:05:37,129 --> 02:05:34,679

what are you even thinking if you think

3239
02:05:39,770 --> 02:05:37,139
that that physics needs observers to go

3240
02:05:43,430 --> 02:05:39,780
on it's just the opposite observers are

3241
02:05:46,010 --> 02:05:43,440
physical systems of a certain kind and

3242
02:05:48,890 --> 02:05:46,020
you want the physics

3243
02:05:52,070 --> 02:05:48,900
to describe how they behave

3244
02:05:54,109 --> 02:05:52,080
as by pure analysis of them as physical

3245
02:05:56,030 --> 02:05:54,119
systems and it's the same thing for

3246
02:05:57,589 --> 02:05:56,040
measurement right a measurement whatever

3247
02:05:59,930 --> 02:05:57,599
you call a measurement is just a

3248
02:06:03,169 --> 02:05:59,940
physical interaction between two things

3249
02:06:05,149 --> 02:06:03,179
that's going to be described by some

3250
02:06:07,070 --> 02:06:05,159
physical equations that don't mention

3251
02:06:08,930 --> 02:06:07,080
the word measurement and that's again go

3252
02:06:11,330 --> 02:06:08,940
read Bells against measurement against

3253
02:06:13,850 --> 02:06:11,340
quote measurement he says the term

3254
02:06:16,310 --> 02:06:13,860
measurement should not appear in the

3255
02:06:17,810 --> 02:06:16,320
formulation of any theory that pretends

3256
02:06:19,970 --> 02:06:17,820
to be foundational

3257
02:06:21,470 --> 02:06:19,980
because measurement isn't the right kind

3258
02:06:24,350 --> 02:06:21,480
of concept

3259
02:06:28,550 --> 02:06:24,360
to appear in the foundations of physics

3260
02:06:29,330 --> 02:06:28,560
measurement is a derivative concept

3261
02:06:32,450 --> 02:06:29,340
um

3262
02:06:34,310 --> 02:06:32,460
Observer is a derivative concept

3263
02:06:37,189 --> 02:06:34,320

they shouldn't appear in the foundations

3264
02:06:39,950 --> 02:06:37,199
of physics but lots of people convince

3265
02:06:40,970 --> 02:06:39,960
themselves that you know again here is

3266
02:06:42,830 --> 02:06:40,980
where I think there's something

3267
02:06:44,990 --> 02:06:42,840
semi-mystical

3268
02:06:47,810 --> 02:06:45,000
so there are people who like the idea

3269
02:06:50,209 --> 02:06:47,820
that that observers should become

3270
02:06:52,010 --> 02:06:50,219
Central to the universe

3271
02:06:55,189 --> 02:06:52,020
they liked it

3272
02:06:57,649 --> 02:06:55,199
it just it annoys them that observers

3273
02:07:02,209 --> 02:06:57,659
seem to be this tiny tiny little

3274
02:07:04,310 --> 02:07:02,219
specials class of uh of of of of you

3275
02:07:06,290 --> 02:07:04,320
know humans in particular some tiny

3276
02:07:08,450 --> 02:07:06,300
little you know specs on something not

3277
02:07:10,669 --> 02:07:08,460
playing a very Central role in physics

3278
02:07:13,189 --> 02:07:10,679
and they have an emotional attachment of

3279
02:07:14,870 --> 02:07:13,199
something of some sort but but it seems

3280
02:07:17,089 --> 02:07:14,880
to me contrary to physics as we

3281
02:07:19,010 --> 02:07:17,099
understand it and certainly nobody's

3282
02:07:20,930 --> 02:07:19,020
ever made progress doing that nobody's

3283
02:07:22,430 --> 02:07:20,940
ever made progress saying oh here I'm

3284
02:07:24,470 --> 02:07:22,440
going to write the Observer into the

3285
02:07:26,450 --> 02:07:24,480
foundations of physics

3286
02:07:28,070 --> 02:07:26,460
and people have made progress doing the

3287
02:07:30,649 --> 02:07:28,080
opposite

3288
02:07:33,709 --> 02:07:30,659

okay so two notes Here number one there

3289
02:07:36,410 --> 02:07:33,719
exists perfectly coherent formulations

3290
02:07:39,770 --> 02:07:36,420
theories of quantum mechanics that don't

3291
02:07:42,290 --> 02:07:39,780
involve observers sure okay so that's

3292
02:07:44,629 --> 02:07:42,300
interesting by the way Theory the grw

3293
02:07:47,209 --> 02:07:44,639
collapse Theory I mean the many worlds

3294
02:07:49,010 --> 02:07:47,219
theory in so far as you can make sense

3295
02:07:50,750 --> 02:07:49,020
of it certainly does not make any

3296
02:07:52,910 --> 02:07:50,760
reference to observers

3297
02:07:54,649 --> 02:07:52,920
I mean these are theories where they're

3298
02:07:56,570 --> 02:07:54,659
they're written in the equations I mean

3299
02:07:57,890 --> 02:07:56,580
again Bell says somewhere I want a

3300
02:07:59,510 --> 02:07:57,900
theory where the physics is in the

3301
02:08:01,669 --> 02:07:59,520
equations and not in the surrounding

3302
02:08:04,729 --> 02:08:01,679
talk right

3303
02:08:06,890 --> 02:08:04,739
um the these are all theories where you

3304
02:08:09,109 --> 02:08:06,900
postulate a Quantum State maybe you

3305
02:08:11,470 --> 02:08:09,119
postulate some local bubbles in addition

3306
02:08:14,030 --> 02:08:11,480
to that and you write down some clean

3307
02:08:15,890 --> 02:08:14,040
equations about how they behave and

3308
02:08:17,030 --> 02:08:15,900
that's the theory that doesn't mention

3309
02:08:18,470 --> 02:08:17,040
observers it doesn't mention

3310
02:08:20,209 --> 02:08:18,480
measurements it doesn't mention anything

3311
02:08:22,910 --> 02:08:20,219
like that there's some physical stuff

3312
02:08:25,250 --> 02:08:22,920
that you postulate it behaves in a

3313
02:08:27,350 --> 02:08:25,260

certain way that you postulate and then

3314
02:08:28,970 --> 02:08:27,360
you see what happens so pilot wave many

3315
02:08:31,870 --> 02:08:28,980
worlds and then what what were the other

3316
02:08:34,669 --> 02:08:31,880
the collapse Theory

3317
02:08:35,930 --> 02:08:34,679
romini Weber objective collapse theories

3318
02:08:37,970 --> 02:08:35,940
there I mean there are class of

3319
02:08:40,370 --> 02:08:37,980
objective object so-called objective

3320
02:08:41,930 --> 02:08:40,380
reduction theories I mean Penrose has a

3321
02:08:43,550 --> 02:08:41,940
kind of sketch of a theory for many

3322
02:08:46,430 --> 02:08:43,560
years he's had a sketch of a theory

3323
02:08:48,770 --> 02:08:46,440
which ties the collapses to gravity the

3324
02:08:51,050 --> 02:08:48,780
grw theory doesn't you know what do you

3325
02:08:55,370 --> 02:08:51,060
make of penrose's theory

3326
02:08:59,030 --> 02:08:55,380
I mean I I understand he he takes the

3327
02:09:02,209 --> 02:08:59,040
foundational questions seriously

3328
02:09:05,810 --> 02:09:02,219
and foundationally

3329
02:09:07,930 --> 02:09:05,820
you only have three options okay that's

3330
02:09:11,149 --> 02:09:07,940
why you can kind of have a nice

3331
02:09:14,330 --> 02:09:11,159
taxonomy of

3332
02:09:16,790 --> 02:09:14,340
solutions to the measurement problem

3333
02:09:19,310 --> 02:09:16,800
you can say that

3334
02:09:20,810 --> 02:09:19,320
you you what you do is just logically

3335
02:09:24,169 --> 02:09:20,820
you get into trouble if you try to

3336
02:09:26,629 --> 02:09:24,179
maintain three principles principle one

3337
02:09:28,310 --> 02:09:26,639
that the wave function

3338
02:09:30,770 --> 02:09:28,320

that's used in all these quantum

3339
02:09:33,530 --> 02:09:30,780
theories provides a complete description

3340
02:09:37,189 --> 02:09:33,540
of a physical system and this was the

3341
02:09:39,410 --> 02:09:37,199
epr paper in 1935 the Einstein Podolski

3342
02:09:40,970 --> 02:09:39,420
Rosen paper the title of it is the

3343
02:09:44,510 --> 02:09:40,980
quantum mechanical description of

3344
02:09:47,810 --> 02:09:44,520
reality complete meaning if I give you

3345
02:09:50,810 --> 02:09:47,820
the wave function can you somehow derive

3346
02:09:52,850 --> 02:09:50,820
from it all the physical facts about the

3347
02:09:55,129 --> 02:09:52,860
system they were arguing you can't they

3348
02:09:58,189 --> 02:09:55,139
were arguing it's incomplete okay

3349
02:09:59,930 --> 02:09:58,199
many war and Heisenberg wanted to say it

3350
02:10:02,629 --> 02:09:59,940
was complete so you have one principle

3351
02:10:04,850 --> 02:10:02,639
is the wave function complete

3352
02:10:06,910 --> 02:10:04,860
the second question does it always

3353
02:10:09,109 --> 02:10:06,920
evolve by Schrodinger's equation

3354
02:10:11,209 --> 02:10:09,119
Schrodinger's equation is linear that's

3355
02:10:13,550 --> 02:10:11,219
a very important feature of it

3356
02:10:15,830 --> 02:10:13,560
third claim is that when you do a

3357
02:10:17,689 --> 02:10:15,840
Schrodinger cat experiment the cat the

3358
02:10:20,089 --> 02:10:17,699
single cat you start with one cat you

3359
02:10:22,430 --> 02:10:20,099
end with one cat and the single cat is

3360
02:10:23,870 --> 02:10:22,440
either alive or dead Okay that was

3361
02:10:25,550 --> 02:10:23,880
Schrodinger's point he thought that's

3362
02:10:27,890 --> 02:10:25,560
obvious

3363
02:10:29,629 --> 02:10:27,900

you can't maintain all three right you

3364
02:10:31,310 --> 02:10:29,639
just as a matter of logic you can't

3365
02:10:32,870 --> 02:10:31,320
maintain the wave function is complete

3366
02:10:34,790 --> 02:10:32,880
that it always involves by Schrodinger's

3367
02:10:35,930 --> 02:10:34,800
equation and that the cat ends up alive

3368
02:10:37,550 --> 02:10:35,940
or dead

3369
02:10:40,010 --> 02:10:37,560
what does it complete mean once more

3370
02:10:42,350 --> 02:10:40,020
what does complete mean it complete

3371
02:10:44,930 --> 02:10:42,360
means if I give you the wave function of

3372
02:10:49,070 --> 02:10:44,940
a system you can derive from that

3373
02:10:51,350 --> 02:10:49,080
somehow all the physical facts about it

3374
02:10:53,390 --> 02:10:51,360
all of its physical characteristics does

3375
02:10:55,250 --> 02:10:53,400
that mean that it has that you could

3376
02:10:56,930 --> 02:10:55,260
find out whether it's spin up and then

3377
02:10:58,609 --> 02:10:56,940
spin it means you could find out

3378
02:10:59,810 --> 02:10:58,619
anything that's a physical fact about it

3379
02:11:03,350 --> 02:10:59,820
I'm not telling you what the physical

3380
02:11:06,770 --> 02:11:03,360
facts are but any physical fact

3381
02:11:08,930 --> 02:11:06,780
is determined by the wave function

3382
02:11:13,010 --> 02:11:08,940
so are there theories that say no you

3383
02:11:15,050 --> 02:11:13,020
can't sure that pilot wave theory ah

3384
02:11:16,910 --> 02:11:15,060
Deborah I mean the de Broly boom or

3385
02:11:18,229 --> 02:11:16,920
bromine mechanics okay in in bohomian

3386
02:11:20,870 --> 02:11:18,239
mechanics

3387
02:11:23,270 --> 02:11:20,880
the ontology the Bibles there too

3388
02:11:25,070 --> 02:11:23,280

there's the universal wave function of

3389
02:11:26,870 --> 02:11:25,080
the universal Quantum State that's one

3390
02:11:28,430 --> 02:11:26,880
and then there are these particles and

3391
02:11:30,410 --> 02:11:28,440
the particles are just classical Point

3392
02:11:32,089 --> 02:11:30,420
particles they have always have definite

3393
02:11:33,530 --> 02:11:32,099
positions they move around

3394
02:11:35,810 --> 02:11:33,540
okay

3395
02:11:37,129 --> 02:11:35,820
but if I just give you the quantum State

3396
02:11:38,570 --> 02:11:37,139
you that doesn't tell you where the

3397
02:11:40,370 --> 02:11:38,580
particles are the where the particles

3398
02:11:42,649 --> 02:11:40,380
are the actual configuration of

3399
02:11:44,209 --> 02:11:42,659
particles is not derivable from that

3400
02:11:46,010 --> 02:11:44,219
it's an additional piece of physical

3401
02:11:48,109 --> 02:11:46,020
data

3402
02:11:50,270 --> 02:11:48,119
and the way that theory works is you say

3403
02:11:52,790 --> 02:11:50,280
okay how does the wave function evolve

3404
02:11:55,189 --> 02:11:52,800
answer Always by Schrodinger's equation

3405
02:11:56,750 --> 02:11:55,199
okay how do the particles move how does

3406
02:11:58,669 --> 02:11:56,760
this particle configuration change

3407
02:12:00,649 --> 02:11:58,679
that's given by a second equation called

3408
02:12:02,990 --> 02:12:00,659
the guidance equation and the guidance

3409
02:12:04,189 --> 02:12:03,000
equation has as an input to it the wave

3410
02:12:06,169 --> 02:12:04,199
function

3411
02:12:08,450 --> 02:12:06,179
so that's a theory where you say the

3412
02:12:10,070 --> 02:12:08,460
wave function is not complete there are

3413
02:12:11,990 --> 02:12:10,080

there are additional physical facts

3414
02:12:14,450 --> 02:12:12,000
really oh sorry I understand what you're

3415
02:12:16,070 --> 02:12:14,460
saying now yes all right I got it yeah I

3416
02:12:17,930 --> 02:12:16,080
could have two systems that have exactly

3417
02:12:19,729 --> 02:12:17,940
the same Quantum state but are different

3418
02:12:21,530 --> 02:12:19,739
physically because the particles are in

3419
02:12:24,229 --> 02:12:21,540
different locations

3420
02:12:26,089 --> 02:12:24,239
right so you can't maintain that the

3421
02:12:28,490 --> 02:12:26,099
wave function is complete and it always

3422
02:12:30,350 --> 02:12:28,500
evolves by Schrodinger's equation and

3423
02:12:33,109 --> 02:12:30,360
that the cat ends up either just playing

3424
02:12:35,450 --> 02:12:33,119
alive or plain dead okay got to give up

3425
02:12:37,010 --> 02:12:35,460
one of those three if you give up the

3426
02:12:38,270 --> 02:12:37,020
completeness of the wave function then

3427
02:12:40,310 --> 02:12:38,280
you have what's called a hidden

3428
02:12:41,570 --> 02:12:40,320
variables Theory like bohmian mechanics

3429
02:12:43,910 --> 02:12:41,580
pilot wave

3430
02:12:45,649 --> 02:12:43,920
if you give up the Schrodinger Evolution

3431
02:12:47,990 --> 02:12:45,659
then you have an objective collapse

3432
02:12:50,390 --> 02:12:48,000
Theory you say okay the wave function

3433
02:12:51,530 --> 02:12:50,400
doesn't always evolve by Schroeder's

3434
02:12:53,930 --> 02:12:51,540
equation

3435
02:12:55,729 --> 02:12:53,940
and if you don't give up those two then

3436
02:12:57,770 --> 02:12:55,739
you're stuck with many worlds and you

3437
02:12:59,990 --> 02:12:57,780
say well the cat doesn't end up either

3438
02:13:02,209 --> 02:13:00,000

alive or dead somehow one cat becomes

3439
02:13:04,510 --> 02:13:02,219
two cats or many cats some of which are

3440
02:13:06,770 --> 02:13:04,520
alive and some of which are dead okay

3441
02:13:08,930 --> 02:13:06,780
those are your only three options just

3442
02:13:10,609 --> 02:13:08,940
as a matter of logic

3443
02:13:12,410 --> 02:13:10,619
I mean I have a paper about this called

3444
02:13:14,750 --> 02:13:12,420
three measurement problems which goes

3445
02:13:16,370 --> 02:13:14,760
through in more detail this is a nice

3446
02:13:18,830 --> 02:13:16,380
thing because if somebody says here's my

3447
02:13:20,450 --> 02:13:18,840
understanding of quantum mechanics you

3448
02:13:22,550 --> 02:13:20,460
can immediately ask them these

3449
02:13:24,589 --> 02:13:22,560
diagnostic questions okay according to

3450
02:13:25,790 --> 02:13:24,599
the quantum State complete according to

3451
02:13:27,770 --> 02:13:25,800
you does it always evolve by

3452
02:13:30,050 --> 02:13:27,780
Schrodinger's equation according to you

3453
02:13:33,109 --> 02:13:30,060
does a single Cat end up either just

3454
02:13:37,270 --> 02:13:33,119
alive or just dead and if they say

3455
02:13:39,530 --> 02:13:37,280
oh I I you know I want to maintain

3456
02:13:41,270 --> 02:13:39,540
the kind of intuitive answer to all

3457
02:13:43,370 --> 02:13:41,280
three say I'm sorry you can't right then

3458
02:13:45,350 --> 02:13:43,380
then it's not a coherent Theory

3459
02:13:46,729 --> 02:13:45,360
um and once they answer which one

3460
02:13:48,530 --> 02:13:46,739
they're going to give up of those three

3461
02:13:49,729 --> 02:13:48,540
then you sort of understand where you

3462
02:13:51,950 --> 02:13:49,739
are and you understand how the

3463
02:13:53,149 --> 02:13:51,960

questioning goes on from there

3464
02:13:56,270 --> 02:13:53,159
um

3465
02:13:57,830 --> 02:13:56,280
so yeah this is extremely extremely

3466
02:14:01,069 --> 02:13:57,840
important yeah

3467
02:14:02,990 --> 02:14:01,079
so I mean look Penrose Penrose has gone

3468
02:14:05,330 --> 02:14:03,000
for an objective reduction theory and

3469
02:14:07,250 --> 02:14:05,340
that this follows if you go and read Von

3470
02:14:09,830 --> 02:14:07,260
Neumann's book mathematical foundations

3471
02:14:12,830 --> 02:14:09,840
of quantum mechanics Von Neumann and

3472
02:14:15,589 --> 02:14:12,840
this was taken as kind of the Bible of

3473
02:14:17,089 --> 02:14:15,599
a clean mathematical formulation of

3474
02:14:20,089 --> 02:14:17,099
Copenhagen

3475
02:14:22,850 --> 02:14:20,099
Von Neumann is very clear he says States

3476
02:14:26,030 --> 02:14:22,860
physical systems can undergo two

3477
02:14:28,490 --> 02:14:26,040
completely different sorts of evolution

3478
02:14:29,990 --> 02:14:28,500
process a and process B of process one

3479
02:14:31,910 --> 02:14:30,000
and process two I can't remember what he

3480
02:14:33,649 --> 02:14:31,920
uses one of them is Schrodinger

3481
02:14:35,750 --> 02:14:33,659
Evolution and the other is a collapse

3482
02:14:38,870 --> 02:14:35,760
right right right and they're very

3483
02:14:40,490 --> 02:14:38,880
different and if if you think that then

3484
02:14:42,169 --> 02:14:40,500
you have an object objective reduction

3485
02:14:44,390 --> 02:14:42,179
theory now that's the way Penrose wanted

3486
02:14:46,189 --> 02:14:44,400
to go for a long time

3487
02:14:47,750 --> 02:14:46,199
and then the question if you have a

3488
02:14:49,430 --> 02:14:47,760

reduction theory you say okay well when

3489
02:14:50,689 --> 02:14:49,440
does this collapse occur what triggers

3490
02:14:55,370 --> 02:14:50,699
the collapse

3491
02:14:57,290 --> 02:14:55,380
will

3492
02:14:58,609 --> 02:14:57,300
um you better not say Well it collapses

3493
02:15:00,169 --> 02:14:58,619
when you make a measurement because then

3494
02:15:01,970 --> 02:15:00,179
you what when do you make a measurement

3495
02:15:03,530 --> 02:15:01,980
there's a measurement now you're back to

3496
02:15:06,290 --> 02:15:03,540
against measurement

3497
02:15:08,209 --> 02:15:06,300
Penrose wanted to tie the collapses to

3498
02:15:11,510 --> 02:15:08,219
gravity somehow

3499
02:15:14,390 --> 02:15:11,520
and he had a sort of

3500
02:15:16,189 --> 02:15:14,400
slightly hand wavy account of that which

3501
02:15:18,770 --> 02:15:16,199
actually a similar account was given by

3502
02:15:20,629 --> 02:15:18,780
a guy named karolihazi long ago he was

3503
02:15:22,970 --> 02:15:20,639
also when corollary housing was great I

3504
02:15:25,490 --> 02:15:22,980
heard him once when I was very young and

3505
02:15:27,830 --> 02:15:25,500
he would say well as it were you have

3506
02:15:29,810 --> 02:15:27,840
these two gravitational situations which

3507
02:15:31,910 --> 02:15:29,820
by Schrodinger evolution

3508
02:15:33,950 --> 02:15:31,920
it's like you know the they're they're

3509
02:15:35,209 --> 02:15:33,960
they're they're separating and the gra

3510
02:15:37,729 --> 02:15:35,219
there's a gravitational difference

3511
02:15:40,069 --> 02:15:37,739
between them and then it's at some point

3512
02:15:41,569 --> 02:15:40,079
that gravitational gets so big and this

3513
02:15:44,569 --> 02:15:41,579

is what corollary houses said he said

3514
02:15:46,430 --> 02:15:44,579
then Gabriel comes and blows his trumpet

3515
02:15:48,649 --> 02:15:46,440
and the blowing of the trumpet was the

3516
02:15:50,689 --> 02:15:48,659
signal the wave function shall now

3517
02:15:53,030 --> 02:15:50,699
collapse and it'll either go this way or

3518
02:15:55,669 --> 02:15:53,040
that way right

3519
02:15:57,890 --> 02:15:55,679
and so you know penrose's idea was to

3520
02:16:01,129 --> 02:15:57,900
tie somehow these collapses to to

3521
02:16:02,689 --> 02:16:01,139
gravity uh the gerardi Remini Weber

3522
02:16:04,669 --> 02:16:02,699
Theory doesn't do that it doesn't tie

3523
02:16:06,470 --> 02:16:04,679
them to anything it just gives you a

3524
02:16:09,169 --> 02:16:06,480
fixed probability per unit time per

3525
02:16:10,729 --> 02:16:09,179
particle that they'll be a collapse so

3526
02:16:12,050 --> 02:16:10,739
these are objective reduction theories

3527
02:16:14,209 --> 02:16:12,060
it's a way to go

3528
02:16:15,649 --> 02:16:14,219
they the objective reduction theories

3529
02:16:18,589 --> 02:16:15,659
make in principles slightly different

3530
02:16:20,270 --> 02:16:18,599
predictions empirical predictions uh

3531
02:16:23,270 --> 02:16:20,280
than the other theories so you can kind

3532
02:16:24,229 --> 02:16:23,280
of test in the lab and the grw kind of

3533
02:16:26,149 --> 02:16:24,239
theory

3534
02:16:28,970 --> 02:16:26,159
I mean people keep doing tests and

3535
02:16:30,890 --> 02:16:28,980
ruling out certain parameters space and

3536
02:16:32,570 --> 02:16:30,900
there's not much parameter space left

3537
02:16:34,429 --> 02:16:32,580
for it

3538
02:16:37,129 --> 02:16:34,439

um in another 10 years it may be

3539
02:16:39,889 --> 02:16:37,139
empirically empirically refuted to

3540
02:16:41,690 --> 02:16:39,899
reiterate its completeness so is there

3541
02:16:43,549 --> 02:16:41,700
more information necessary to specify

3542
02:16:45,169 --> 02:16:43,559
what's physically going on and in the

3543
02:16:46,969 --> 02:16:45,179
case just to be clear again balmian

3544
02:16:50,270 --> 02:16:46,979
mechanics and pilot wave are synonyms

3545
02:16:52,310 --> 02:16:50,280
yeah okay and then so in Pilot wave

3546
02:16:53,209 --> 02:16:52,320
theory it says there's a wave and a

3547
02:16:59,030 --> 02:16:53,219
pilot

3548
02:17:01,070 --> 02:16:59,040
wave the quantum State call it the

3549
02:17:03,349 --> 02:17:01,080
quantum State that's the thing that's

3550
02:17:04,490 --> 02:17:03,359
described mathematically by the wave

3551
02:17:05,530 --> 02:17:04,500
function

3552
02:17:09,770 --> 02:17:05,540
okay

3553
02:17:13,849 --> 02:17:09,780
it's job physically is to Pilot or guide

3554
02:17:15,650 --> 02:17:13,859
the particles okay to determine how the

3555
02:17:19,370 --> 02:17:15,660
particles move

3556
02:17:22,129 --> 02:17:19,380
and it does so via a a precise equation

3557
02:17:24,709 --> 02:17:22,139
called the guidance equation

3558
02:17:26,570 --> 02:17:24,719
I mean bell bell presented it that way

3559
02:17:29,030 --> 02:17:26,580
but boom when he did it I mean the

3560
02:17:30,950 --> 02:17:29,040
original idea was de broily and then de

3561
02:17:32,509 --> 02:17:30,960
broily dropped it for bad reasons and

3562
02:17:34,009 --> 02:17:32,519
then bone rediscovered it but bone

3563
02:17:35,570 --> 02:17:34,019

presented the theory as a kind of

3564
02:17:37,370 --> 02:17:35,580
Newtonian Theory with something he

3565
02:17:39,469 --> 02:17:37,380
called the quantum potential that turns

3566
02:17:41,209 --> 02:17:39,479
out to be a bad idea Bell presented it

3567
02:17:43,370 --> 02:17:41,219
in terms of the guidance equation which

3568
02:17:46,310 --> 02:17:43,380
is the right way to do it

3569
02:17:48,290 --> 02:17:46,320
um so the piloting is done by the way as

3570
02:17:51,290 --> 02:17:48,300
it were by the quantum State and what

3571
02:17:53,810 --> 02:17:51,300
pilots or what it guides are the part of

3572
02:17:55,730 --> 02:17:53,820
it a surfer on the wave is the particle

3573
02:17:58,070 --> 02:17:55,740
something like that you can think of it

3574
02:17:59,870 --> 02:17:58,080
that way now the the thing that you have

3575
02:18:02,150 --> 02:17:59,880
to wrap your head around

3576
02:18:03,709 --> 02:18:02,160
that's hard for this theory is if you

3577
02:18:05,150 --> 02:18:03,719
have a single particle you can really

3578
02:18:07,610 --> 02:18:05,160
think of it that way you've got kind of

3579
02:18:09,589 --> 02:18:07,620
a wave in physical space and it's

3580
02:18:11,089 --> 02:18:09,599
telling the particle where to go but as

3581
02:18:13,730 --> 02:18:11,099
soon as you get two particles or three

3582
02:18:15,950 --> 02:18:13,740
particles or four interact

3583
02:18:18,349 --> 02:18:15,960
whether they interact or not the weight

3584
02:18:21,169 --> 02:18:18,359
function is now defined not on physical

3585
02:18:23,089 --> 02:18:21,179
space but on configuration space which

3586
02:18:25,009 --> 02:18:23,099
is of Three N Dimension so for four

3587
02:18:27,110 --> 02:18:25,019
particles it's a 12 dimensional space

3588
02:18:28,849 --> 02:18:27,120

and this is just standard quantum

3589
02:18:30,549 --> 02:18:28,859
mechanics this is not peculiar to this

3590
02:18:33,589 --> 02:18:30,559
Theory

3591
02:18:35,929 --> 02:18:33,599
and essentially what that high

3592
02:18:38,509 --> 02:18:35,939
dimensional object is doing is governing

3593
02:18:41,030 --> 02:18:38,519
the entire configuration of particles it

3594
02:18:42,349 --> 02:18:41,040
it doesn't it's not as if as it were one

3595
02:18:44,030 --> 02:18:42,359
part of the wave is telling this

3596
02:18:45,469 --> 02:18:44,040
particle where to go and another part of

3597
02:18:47,690 --> 02:18:45,479
the wave is telling this particle while

3598
02:18:50,089 --> 02:18:47,700
ago is that the whole wave is telling

3599
02:18:52,730 --> 02:18:50,099
the entire collection of particles

3600
02:18:55,009 --> 02:18:52,740
how to evolve that's why it's a kind of

3601
02:18:57,410 --> 02:18:55,019
non-local theory that's why that's how

3602
02:18:59,990 --> 02:18:57,420
the non-locality gets into it it's a

3603
02:19:02,089 --> 02:19:00,000
kind of global holistic Theory where

3604
02:19:03,709 --> 02:19:02,099
everything is being done together at the

3605
02:19:05,089 --> 02:19:03,719
same time

3606
02:19:07,849 --> 02:19:05,099
if you will

3607
02:19:09,469 --> 02:19:07,859
are there separate pilot waves for each

3608
02:19:11,450 --> 02:19:09,479
of the particles or is there one pilot

3609
02:19:12,950 --> 02:19:11,460
wave no no there is one I mean in this

3610
02:19:15,830 --> 02:19:12,960
theory if you take it seriously

3611
02:19:17,929 --> 02:19:15,840
ultimately there is one Quantum State

3612
02:19:20,810 --> 02:19:17,939
and that one Quantum state is the

3613
02:19:23,629 --> 02:19:20,820

Quantum state of the entire universe

3614
02:19:25,669 --> 02:19:23,639
and what it determines is how the entire

3615
02:19:27,950 --> 02:19:25,679
configuration of everything in the

3616
02:19:29,690 --> 02:19:27,960
universe behaves

3617
02:19:32,089 --> 02:19:29,700
and then there's a very interesting

3618
02:19:33,650 --> 02:19:32,099
question which to which there's very

3619
02:19:34,730 --> 02:19:33,660
there are very interesting and precise

3620
02:19:36,650 --> 02:19:34,740
answers

3621
02:19:38,389 --> 02:19:36,660
well if that's true that's not what we

3622
02:19:39,950 --> 02:19:38,399
ever use in our calculations right when

3623
02:19:43,330 --> 02:19:39,960
I go into the lab

3624
02:19:47,990 --> 02:19:43,340
I don't use the universal wave function

3625
02:19:50,030 --> 02:19:48,000
of everything I assign a little size so

3626
02:19:51,770 --> 02:19:50,040
in the in the literature those big PSI

3627
02:19:53,450 --> 02:19:51,780
which is the fundamental thing it's the

3628
02:19:55,130 --> 02:19:53,460
wave function of everything the entire

3629
02:19:56,570 --> 02:19:55,140
universe and then there's little PSI

3630
02:19:58,790 --> 02:19:56,580
which is something I would assign to a

3631
02:20:00,830 --> 02:19:58,800
subsystem and then there's a question of

3632
02:20:02,929 --> 02:20:00,840
well how do what's the status of this

3633
02:20:04,670 --> 02:20:02,939
little side that I actually use and

3634
02:20:06,410 --> 02:20:04,680
there's a very nice answer to that it's

3635
02:20:08,150 --> 02:20:06,420
called the conditional wave function the

3636
02:20:11,270 --> 02:20:08,160
answer is mathematically clear this is

3637
02:20:14,110 --> 02:20:11,280
all covered in my book as well uh and

3638
02:20:16,370 --> 02:20:14,120

the conditional wave function

3639
02:20:17,870 --> 02:20:16,380
sometimes evolves by Schrodinger's

3640
02:20:19,670 --> 02:20:17,880
equation and sometimes does something

3641
02:20:22,250 --> 02:20:19,680
that looks like a collapse

3642
02:20:25,370 --> 02:20:22,260
interesting and all of that is just a

3643
02:20:27,770 --> 02:20:25,380
consequence of these two equations that

3644
02:20:29,210 --> 02:20:27,780
are at Universal scale

3645
02:20:34,070 --> 02:20:29,220
so there's a really beautiful

3646
02:20:36,889 --> 02:20:34,080
explanation in this theory of why people

3647
02:20:39,190 --> 02:20:36,899
use collapses to do calculations and to

3648
02:20:41,990 --> 02:20:39,200
the the extent to which that's Justified

3649
02:20:44,870 --> 02:20:42,000
even though in this Theory there are no

3650
02:20:46,730 --> 02:20:44,880
collapses on the single fundamental

3651
02:20:48,950 --> 02:20:46,740
Quantum state which is the Quantum state

3652
02:20:50,270 --> 02:20:48,960
of the entire universe there's a

3653
02:20:51,650 --> 02:20:50,280
wonderful answer to that and it's an

3654
02:20:53,330 --> 02:20:51,660
answer that's not available in other

3655
02:20:55,010 --> 02:20:53,340
theories I mean there's a nice story to

3656
02:20:57,230 --> 02:20:55,020
be told and you use this word theories

3657
02:20:59,290 --> 02:20:57,240
which is interesting because when one

3658
02:21:01,730 --> 02:20:59,300
takes quantum mechanics and University

3659
02:21:04,130 --> 02:21:01,740
they're taught or they're told you're

3660
02:21:06,290 --> 02:21:04,140
going to learn quantum theory and you

3661
02:21:08,990 --> 02:21:06,300
would say at least from my observation

3662
02:21:11,030 --> 02:21:09,000
from your talks well a theory needs to

3663
02:21:13,250 --> 02:21:11,040

have an account of what is so he needs

3664
02:21:15,410 --> 02:21:13,260
to have some ontology or some way that

3665
02:21:16,990 --> 02:21:15,420
the mathematics relates to what is you

3666
02:21:19,550 --> 02:21:17,000
can't just speak about the mathematics

3667
02:21:22,130 --> 02:21:19,560
so that's why

3668
02:21:23,150 --> 02:21:22,140
you are not calling I've been listening

3669
02:21:24,590 --> 02:21:23,160
to you you're not calling these

3670
02:21:25,790 --> 02:21:24,600
interpretations of quantum mechanics you

3671
02:21:28,190 --> 02:21:25,800
kept saying these are different theories

3672
02:21:30,290 --> 02:21:28,200
because you don't see quantum theory as

3673
02:21:31,790 --> 02:21:30,300
having multiple interpretations you see

3674
02:21:34,250 --> 02:21:31,800
each of them as separate quantum

3675
02:21:36,050 --> 02:21:34,260
theories that's right well my view is

3676
02:21:37,429 --> 02:21:36,060
very I mean I say it over and over again

3677
02:21:40,010 --> 02:21:37,439
I don't really know how anyone would

3678
02:21:42,770 --> 02:21:40,020
dispute it what you're taught when you

3679
02:21:45,950 --> 02:21:42,780
take a course is not a theory why

3680
02:21:48,290 --> 02:21:45,960
because a theory postulates

3681
02:21:50,750 --> 02:21:48,300
the existence of certain things it tells

3682
02:21:52,670 --> 02:21:50,760
you look here's what here I am a theory

3683
02:21:55,309 --> 02:21:52,680
about the physical world here's what I'm

3684
02:21:57,110 --> 02:21:55,319
saying is in the physical world and

3685
02:22:00,349 --> 02:21:57,120
here's how it behaves that's what a

3686
02:22:04,010 --> 02:22:00,359
physical theory is what you're taught is

3687
02:22:07,309 --> 02:22:04,020
a scheme for making predictions

3688
02:22:10,910 --> 02:22:07,319

okay it's a predictive recipe

3689
02:22:13,070 --> 02:22:10,920
it says oh in this circumstance use this

3690
02:22:15,410 --> 02:22:13,080
mathematical object and solve it in this

3691
02:22:18,410 --> 02:22:15,420
way and then you pull pull out of thin

3692
02:22:19,670 --> 02:22:18,420
airborne's rule to make probabilistic

3693
02:22:21,710 --> 02:22:19,680
predictions okay it's a

3694
02:22:23,750 --> 02:22:21,720
prediction-making apparatus

3695
02:22:25,910 --> 02:22:23,760
but it doesn't even attempt to be a

3696
02:22:27,530 --> 02:22:25,920
theory it doesn't pretend to be a theory

3697
02:22:30,290 --> 02:22:27,540
because if it were a theory you could

3698
02:22:31,490 --> 02:22:30,300
say okay how do I understand this wave

3699
02:22:33,290 --> 02:22:31,500
function that you're using does that

3700
02:22:34,429 --> 02:22:33,300
represent anything physically real and

3701
02:22:37,010 --> 02:22:34,439
it would give you an answer the answer

3702
02:22:39,290 --> 02:22:37,020
might be yes the answer might be no but

3703
02:22:41,929 --> 02:22:39,300
it would be an answer and what you're

3704
02:22:44,150 --> 02:22:41,939
taught doesn't give you an answer

3705
02:22:46,490 --> 02:22:44,160
that's why people use this phrase shut

3706
02:22:48,590 --> 02:22:46,500
up and calculate

3707
02:22:50,330 --> 02:22:48,600
they'd say look I've given you this wave

3708
02:22:52,910 --> 02:22:50,340
function I've told you how to manipulate

3709
02:22:54,770 --> 02:22:52,920
it to make your predictions now shut up

3710
02:22:57,170 --> 02:22:54,780
and calculate don't ask me whether it

3711
02:22:59,270 --> 02:22:57,180
represents anything physically real and

3712
02:23:01,370 --> 02:22:59,280
so it's not a theory and then what

3713
02:23:04,070 --> 02:23:01,380

people call interpretations of quantum

3714
02:23:07,070 --> 02:23:04,080
theory are really explicit physical

3715
02:23:09,050 --> 02:23:07,080
theories that make precise postulates

3716
02:23:11,330 --> 02:23:09,060
about what exists and how it behaves

3717
02:23:15,590 --> 02:23:11,340
that are designed

3718
02:23:17,690 --> 02:23:15,600
to give you within Epsilon sometimes not

3719
02:23:19,070 --> 02:23:17,700
exactly but pretty nearly the

3720
02:23:21,650 --> 02:23:19,080
predictions that come out of this

3721
02:23:23,630 --> 02:23:21,660
predictive recipe what's wrong with the

3722
02:23:25,969 --> 02:23:23,640
shut up and calculate mindset

3723
02:23:27,349 --> 02:23:25,979
so why can't we simply have both hey

3724
02:23:30,230 --> 02:23:27,359
there are some people who are going to

3725
02:23:31,969 --> 02:23:30,240
investigate Subterranean find the Sharks

3726
02:23:33,410 --> 02:23:31,979
and the giant squid and then there are

3727
02:23:35,270 --> 02:23:33,420
those on the top they're like hey I'm

3728
02:23:37,550 --> 02:23:35,280
gonna build the cities and make

3729
02:23:39,530 --> 02:23:37,560
technology and sure you can say it's

3730
02:23:41,809 --> 02:23:39,540
also exists what difference does it make

3731
02:23:43,670 --> 02:23:41,819
for me at some points you provide

3732
02:23:46,670 --> 02:23:43,680
insights and they come up to the surface

3733
02:23:48,710 --> 02:23:46,680
and maybe we inform you you do you will

3734
02:23:50,150 --> 02:23:48,720
do us is there something wrong with that

3735
02:23:52,550 --> 02:23:50,160
no

3736
02:23:54,950 --> 02:23:52,560
division of labor I mean it's the the

3737
02:23:56,690 --> 02:23:54,960
same division of labor one has typically

3738
02:23:58,610 --> 02:23:56,700

between engineering and fundamental

3739
02:24:00,469 --> 02:23:58,620
physics so let me just give you an

3740
02:24:02,630 --> 02:24:00,479
analogy suppose I'm an engineer I'm

3741
02:24:05,030 --> 02:24:02,640
interested in building bridges

3742
02:24:07,730 --> 02:24:05,040
and I'm just fooling around at some

3743
02:24:10,070 --> 02:24:07,740
point with different metal alloys

3744
02:24:11,690 --> 02:24:10,080
and I make an alloy that has some really

3745
02:24:14,270 --> 02:24:11,700
nice properties for bridge building

3746
02:24:16,429 --> 02:24:14,280
right it's light and it's very sturdy

3747
02:24:18,170 --> 02:24:16,439
and so on and I say ah good

3748
02:24:19,610 --> 02:24:18,180
I'm going to use this to make my bridges

3749
02:24:21,650 --> 02:24:19,620
I can now make lighter Bridges and

3750
02:24:22,910 --> 02:24:21,660
stronger Bridges good as an engineer I'm

3751
02:24:25,070 --> 02:24:22,920
happy

3752
02:24:27,710 --> 02:24:25,080
then somebody comes along and says but

3753
02:24:28,730 --> 02:24:27,720
why that alloy I mean why is that alloy

3754
02:24:31,910 --> 02:24:28,740
so much

3755
02:24:33,710 --> 02:24:31,920
stronger than other Alloys now as an

3756
02:24:36,830 --> 02:24:33,720
engineer I don't have a complaint about

3757
02:24:39,230 --> 02:24:36,840
the engineer saying I don't care

3758
02:24:42,770 --> 02:24:39,240
I don't care why it works I don't need

3759
02:24:44,929 --> 02:24:42,780
to understand why it works for my job I

3760
02:24:47,210 --> 02:24:44,939
just have to know that it works

3761
02:24:49,969 --> 02:24:47,220
I have to know that it is in fact light

3762
02:24:53,450 --> 02:24:49,979
and strong which I can test and look it

3763
02:24:56,030 --> 02:24:53,460

is if you if you physicists want to try

3764
02:24:58,250 --> 02:24:56,040
and figure out why this much bismuth and

3765
02:25:01,309 --> 02:24:58,260
this much tin and this much you know

3766
02:25:04,429 --> 02:25:01,319
Iron happens to form a structure that's

3767
02:25:05,990 --> 02:25:04,439
so light fine go to it I as an engineer

3768
02:25:08,210 --> 02:25:06,000
could not care less

3769
02:25:10,370 --> 02:25:08,220
my job is done when I built the bridge

3770
02:25:12,110 --> 02:25:10,380
and I'm sure it's going to work so

3771
02:25:14,210 --> 02:25:12,120
that's a division of labor

3772
02:25:15,650 --> 02:25:14,220
I'm not gonna I'm not gonna rag on the

3773
02:25:17,450 --> 02:25:15,660
engineer you can say well at least they

3774
02:25:19,550 --> 02:25:17,460
ended up building a bridge you know they

3775
02:25:22,190 --> 02:25:19,560
made life better people can now travel

3776
02:25:26,150 --> 02:25:22,200
across the river I'm not making a value

3777
02:25:27,590 --> 02:25:26,160
judgment I I am saying from my personal

3778
02:25:29,990 --> 02:25:27,600
point of view

3779
02:25:33,230 --> 02:25:30,000
I want to know why it works

3780
02:25:38,889 --> 02:25:33,240
it's not to me I'm just a nosy person

3781
02:25:41,690 --> 02:25:38,899
okay I'm not focused on on uh practical

3782
02:25:44,389 --> 02:25:41,700
outcomes I'm just not I'm not saying a

3783
02:25:46,130 --> 02:25:44,399
curious person I'm just curious I would

3784
02:25:48,290 --> 02:25:46,140
be interested to know why that

3785
02:25:51,410 --> 02:25:48,300
particular mix of metals

3786
02:25:53,090 --> 02:25:51,420
is so much better than other mixes of

3787
02:25:56,030 --> 02:25:53,100
metals and that's the kind of thing that

3788
02:25:59,270 --> 02:25:56,040

the physicists would get into and try to

3789
02:26:01,370 --> 02:25:59,280
describe in fine detail what's this

3790
02:26:04,309 --> 02:26:01,380
underlying structure

3791
02:26:06,590 --> 02:26:04,319
now you know some physicists have

3792
02:26:07,969 --> 02:26:06,600
decided from my point of view when it

3793
02:26:09,469 --> 02:26:07,979
comes to Quantum Mechanics they're happy

3794
02:26:11,690 --> 02:26:09,479
to be engineers

3795
02:26:13,309 --> 02:26:11,700
right they say okay you've given me this

3796
02:26:14,809 --> 02:26:13,319
wave function and you've told me how to

3797
02:26:17,510 --> 02:26:14,819
calculate with it and that's enough for

3798
02:26:20,389 --> 02:26:17,520
me to design my chips or you know blah

3799
02:26:22,130 --> 02:26:20,399
blah blah I'm happy I'm but personally

3800
02:26:23,570 --> 02:26:22,140
I'm not happy I don't really care about

3801
02:26:25,670 --> 02:26:23,580
the chips I want to understand what's

3802
02:26:28,130 --> 02:26:25,680
really going on right I understand what

3803
02:26:29,929 --> 02:26:28,140
the world is really made of so I want to

3804
02:26:32,510 --> 02:26:29,939
go deeper than that but that's that's

3805
02:26:34,969 --> 02:26:32,520
you know I can't say that that's

3806
02:26:38,150 --> 02:26:34,979
intrinsically better thing to do

3807
02:26:42,590 --> 02:26:38,160
certainly you would not have made all

3808
02:26:45,349 --> 02:26:42,600
the material progress that has been made

3809
02:26:47,450 --> 02:26:45,359
using quantum mechanics

3810
02:26:50,210 --> 02:26:47,460
um if people got stuck because they

3811
02:26:53,110 --> 02:26:50,220
didn't understand it right so shut up

3812
02:26:55,730 --> 02:26:53,120
and calculate was efficient

3813
02:26:58,429 --> 02:26:55,740

but it's really bad if people think

3814
02:27:01,070 --> 02:26:58,439
there's something wrong with the small

3815
02:27:03,230 --> 02:27:01,080
minority of us who are not satisfied

3816
02:27:05,870 --> 02:27:03,240
with it right there's something there's

3817
02:27:07,429 --> 02:27:05,880
something illegitimate about people who

3818
02:27:10,730 --> 02:27:07,439
say but I really want to know what's

3819
02:27:12,710 --> 02:27:10,740
going on not for any practical purpose

3820
02:27:14,210 --> 02:27:12,720
and of course most of physics is like

3821
02:27:17,389 --> 02:27:14,220
that I mean when they built the the

3822
02:27:19,490 --> 02:27:17,399
Large Hadron Collider to try and see if

3823
02:27:21,349 --> 02:27:19,500
the Higgs particle existed

3824
02:27:23,990 --> 02:27:21,359
it wasn't because you would make better

3825
02:27:25,910 --> 02:27:24,000
computers or build bigger Bridges or

3826
02:27:28,309 --> 02:27:25,920
have some practical consequence that

3827
02:27:30,190 --> 02:27:28,319
came out of what the exact mass of the

3828
02:27:32,690 --> 02:27:30,200
Higgs is

3829
02:27:34,849 --> 02:27:32,700
nobody could foresee they would have any

3830
02:27:36,410 --> 02:27:34,859
interesting practical consequences

3831
02:27:37,730 --> 02:27:36,420
you're just curious right what's going

3832
02:27:40,490 --> 02:27:37,740
on foreign

3833
02:27:42,590 --> 02:27:40,500
to me that's the fundamental impulse of

3834
02:27:44,570 --> 02:27:42,600
of being interested in physics it's just

3835
02:27:45,590 --> 02:27:44,580
you know falmos it's Wonder at the

3836
02:27:46,910 --> 02:27:45,600
universe it's trying to understand

3837
02:27:49,670 --> 02:27:46,920
things

3838
02:27:51,770 --> 02:27:49,680

now some people

3839
02:27:53,570 --> 02:27:51,780
aren't driven by that and they're more

3840
02:27:55,130 --> 02:27:53,580
interested in building things or they're

3841
02:27:57,170 --> 02:27:55,140
more interested and I I don't want to

3842
02:27:59,210 --> 02:27:57,180
say they're you know what they're doing

3843
02:28:01,190 --> 02:27:59,220
is bad

3844
02:28:03,650 --> 02:28:01,200
but you know we've at least a few of us

3845
02:28:06,349 --> 02:28:03,660
who are motivated by pure intellectual

3846
02:28:08,690 --> 02:28:06,359
curiosity to go about our business

3847
02:28:10,190 --> 02:28:08,700
yes and I find that there's a bit of

3848
02:28:12,290 --> 02:28:10,200
condescension from the hardcore

3849
02:28:14,210 --> 02:28:12,300
physicist toward the philosophers I

3850
02:28:16,610 --> 02:28:14,220
don't know if it's an understatement

3851
02:28:17,929 --> 02:28:16,620
yeah I wish that wasn't there it's

3852
02:28:18,830 --> 02:28:17,939
getting better though it really is

3853
02:28:21,110 --> 02:28:18,840
getting better I mean if you didn't

3854
02:28:23,870 --> 02:28:21,120
notice it was just within the last week

3855
02:28:26,830 --> 02:28:23,880
I think I saw it on Facebook an

3856
02:28:29,389 --> 02:28:26,840
editorial published in

3857
02:28:31,490 --> 02:28:29,399
nature physics

3858
02:28:33,290 --> 02:28:31,500
okay we don't know who wrote it it's

3859
02:28:35,090 --> 02:28:33,300
just an editorial from the editorial

3860
02:28:37,730 --> 02:28:35,100
board not signed

3861
02:28:38,929 --> 02:28:37,740
which is basically saying you know

3862
02:28:40,969 --> 02:28:38,939
there's really a reason to look at

3863
02:28:43,429 --> 02:28:40,979

foundations of physics

3864
02:28:44,750 --> 02:28:43,439
right it's not that everybody has to you

3865
02:28:46,190 --> 02:28:44,760
know Spotlight but it's really a

3866
02:28:48,830 --> 02:28:46,200
worthwhile

3867
02:28:51,410 --> 02:28:48,840
subject matter for physicists to think

3868
02:28:54,969 --> 02:28:51,420
about foundational issues and to me this

3869
02:28:57,650 --> 02:28:54,979
is just wonderful because that's I mean

3870
02:28:59,630 --> 02:28:57,660
I know people I mean I was lucky because

3871
02:29:01,370 --> 02:28:59,640
I'm in the philosophy community and

3872
02:29:03,530 --> 02:29:01,380
philosophers are happy with the

3873
02:29:05,990 --> 02:29:03,540
questions I'm interested in

3874
02:29:07,130 --> 02:29:06,000
but physicists trying to do foundational

3875
02:29:09,110 --> 02:29:07,140
work

3876
02:29:12,170 --> 02:29:09,120
you know I mean they have a very very

3877
02:29:14,870 --> 02:29:12,180
very very very hard time just at a

3878
02:29:16,670 --> 02:29:14,880
practical level because it's not valued

3879
02:29:19,309 --> 02:29:16,680
it's just not valued in physics

3880
02:29:21,710 --> 02:29:19,319
departments it's considered somehow

3881
02:29:23,570 --> 02:29:21,720
illegitimate do you see Consciousness as

3882
02:29:25,429 --> 02:29:23,580
a foundational question

3883
02:29:27,469 --> 02:29:25,439
Consciousness I see is the hardest

3884
02:29:30,770 --> 02:29:27,479
question there is

3885
02:29:31,809 --> 02:29:30,780
I I think the mind-body problem is the

3886
02:29:36,650 --> 02:29:31,819
hardest

3887
02:29:39,290 --> 02:29:36,660
conundrum on hard and that's because you

3888
02:29:41,090 --> 02:29:39,300

can't even imagine what a solution could

3889
02:29:44,270 --> 02:29:41,100
look like right

3890
02:29:46,969 --> 02:29:44,280
right I I don't understand I don't know

3891
02:29:49,250 --> 02:29:46,979
I just could I mean if you sort of think

3892
02:29:51,349 --> 02:29:49,260
I'm going to give an example if you go

3893
02:29:53,090 --> 02:29:51,359
back to ancient Greece and they said I

3894
02:29:54,410 --> 02:29:53,100
wonder what matters made of and the

3895
02:29:57,170 --> 02:29:54,420
atomists

3896
02:29:59,630 --> 02:29:57,180
say well I think it's these little hard

3897
02:30:01,130 --> 02:29:59,640
atoms and all they can do is move and

3898
02:30:02,630 --> 02:30:01,140
some of them have hooks and some of them

3899
02:30:05,630 --> 02:30:02,640
have eyes and sometimes they hook

3900
02:30:08,750 --> 02:30:05,640
together and you know okay

3901
02:30:12,590 --> 02:30:08,760
you can at least understand

3902
02:30:15,050 --> 02:30:12,600
in a sketchy way how such an a postulate

3903
02:30:16,790 --> 02:30:15,060
could account for tables and chairs and

3904
02:30:18,469 --> 02:30:16,800
things burning and you know okay they

3905
02:30:20,630 --> 02:30:18,479
become unhooked or they get hooked or

3906
02:30:22,190 --> 02:30:20,640
blah blah blah I mean at least you see

3907
02:30:23,870 --> 02:30:22,200
maybe it's wrong maybe it's completely

3908
02:30:27,650 --> 02:30:23,880
off Target it turned out it was off

3909
02:30:28,670 --> 02:30:27,660
Target but I mean that's story but at

3910
02:30:31,309 --> 02:30:28,680
least you could see from the beginning

3911
02:30:33,469 --> 02:30:31,319
how if it were true

3912
02:30:36,650 --> 02:30:33,479
it could account for what you want

3913
02:30:40,130 --> 02:30:36,660

accounted for which is the behavior of

3914
02:30:42,590 --> 02:30:40,140
objects at macroscopic scale

3915
02:30:45,650 --> 02:30:42,600
in the case of Consciousness I don't

3916
02:30:49,429 --> 02:30:45,660
even know what a solution to the Mind

3917
02:30:52,389 --> 02:30:51,290
without putting any other constraints I

3918
02:30:55,070 --> 02:30:52,399
just don't know

3919
02:30:57,290 --> 02:30:55,080
essentially what you're asking for is

3920
02:30:59,750 --> 02:30:57,300
some Physics

3921
02:31:01,370 --> 02:30:59,760
that when you apply it to a physical

3922
02:31:05,150 --> 02:31:01,380
body

3923
02:31:08,090 --> 02:31:05,160
in the structural form of a human brain

3924
02:31:11,330 --> 02:31:08,100
or a dog's brain or you know I don't

3925
02:31:12,889 --> 02:31:11,340
know an ant's brain I'm not sure right I

3926
02:31:14,150 --> 02:31:12,899
don't know are ants conscious I don't

3927
02:31:17,270 --> 02:31:14,160
know

3928
02:31:19,370 --> 02:31:17,280
that somehow you see that gee that

3929
02:31:23,090 --> 02:31:19,380
physical Behavior would be accompanied

3930
02:31:27,349 --> 02:31:23,100
by or create or whatever

3931
02:31:31,309 --> 02:31:27,359
a subjective State like pain

3932
02:31:32,929 --> 02:31:31,319
and I don't understand how that could be

3933
02:31:34,790 --> 02:31:32,939
so I think that's the hardest problem

3934
02:31:36,110 --> 02:31:34,800
there is and because it's so hard I

3935
02:31:37,550 --> 02:31:36,120
don't work on it because I don't even

3936
02:31:39,950 --> 02:31:37,560
understand what a solution would look

3937
02:31:41,990 --> 02:31:39,960
like I mean I I've pointed out

3938
02:31:43,309 --> 02:31:42,000

one of the first papers I published was

3939
02:31:45,410 --> 02:31:43,319
a paper called computation and

3940
02:31:47,450 --> 02:31:45,420
Consciousness which is just pointing out

3941
02:31:49,610 --> 02:31:47,460
that a certain kind of attempt to answer

3942
02:31:51,530 --> 02:31:49,620
that question can't be right

3943
02:31:54,830 --> 02:31:51,540
but I don't know what the right answer

3944
02:31:57,889 --> 02:31:54,840
is I don't even know I I I'm you know

3945
02:32:00,050 --> 02:31:57,899
so I it's not that I don't think there's

3946
02:32:02,690 --> 02:32:00,060
a problem there it's I think there's a

3947
02:32:05,510 --> 02:32:02,700
problem there that's so intractable yes

3948
02:32:08,389 --> 02:32:05,520
that I don't want to spend my time

3949
02:32:10,610 --> 02:32:08,399
banging my head against a brick wall now

3950
02:32:12,050 --> 02:32:10,620
I firmly believe I'm not a duelist I

3951
02:32:15,650 --> 02:32:12,060
firmly believe

3952
02:32:18,230 --> 02:32:15,660
that anybody who had a brain

3953
02:32:19,849 --> 02:32:18,240
that was physically identical to mine

3954
02:32:21,410 --> 02:32:19,859
and the neurons and everything were

3955
02:32:23,330 --> 02:32:21,420
doing things physically identical to

3956
02:32:25,250 --> 02:32:23,340
mine they would be having conscious

3957
02:32:27,010 --> 02:32:25,260
experiences that would be qualitatively

3958
02:32:29,750 --> 02:32:27,020
identical to mine

3959
02:32:32,150 --> 02:32:29,760
so I'm not a duelist

3960
02:32:34,849 --> 02:32:32,160
I think that Consciousness in some sense

3961
02:32:37,010 --> 02:32:34,859
supervenes on physical activity because

3962
02:32:38,750 --> 02:32:37,020
I think that's all I am I'm ultimately a

3963
02:32:41,210 --> 02:32:38,760

physical thing

3964
02:32:43,010 --> 02:32:41,220
uh it therefore depends on quantum

3965
02:32:46,010 --> 02:32:43,020
mechanics just because physics depends

3966
02:32:47,870 --> 02:32:46,020
on quantum mechanics but I I I don't see

3967
02:32:50,030 --> 02:32:47,880
I don't see

3968
02:32:52,130 --> 02:32:50,040
any clue

3969
02:32:58,030 --> 02:32:52,140
of

3970
02:33:05,510 --> 02:33:00,349
subjective physical States should

3971
02:33:08,210 --> 02:33:05,520
accompany any sort of physical activity

3972
02:33:11,090 --> 02:33:08,220
so you know you work where you think you

3973
02:33:12,950 --> 02:33:11,100
can make progress and you just you know

3974
02:33:15,770 --> 02:33:12,960
you acknowledge where you don't think

3975
02:33:17,809 --> 02:33:15,780
you can and where there are problems

3976
02:33:19,429 --> 02:33:17,819
um you mentioned that you ruled out a

3977
02:33:21,290 --> 02:33:19,439
certain class of Consciousness theories

3978
02:33:22,370 --> 02:33:21,300
that are computational yeah I don't know

3979
02:33:24,349 --> 02:33:22,380
if that was the correct wording

3980
02:33:25,849 --> 02:33:24,359
regardless can you expound on that is

3981
02:33:28,010 --> 02:33:25,859
this similar to the Penrose Lucas

3982
02:33:30,230 --> 02:33:28,020
argument there's a whole there's a whole

3983
02:33:32,030 --> 02:33:30,240
class of theories that that are called

3984
02:33:34,969 --> 02:33:32,040
functionalists

3985
02:33:37,610 --> 02:33:34,979
and the basic idea is

3986
02:33:39,469 --> 02:33:37,620
what makes a system conscious is kind of

3987
02:33:42,469 --> 02:33:39,479
independent of the particular physical

3988
02:33:45,590 --> 02:33:42,479

stuff it's made of it's rather how that

3989
02:33:47,570 --> 02:33:45,600
physical stuff behaves

3990
02:33:49,429 --> 02:33:47,580
um functions in a certain way

3991
02:33:52,250 --> 02:33:49,439
this is sorry is this the same as

3992
02:33:53,809 --> 02:33:52,260
substrate Independence or no yeah it's a

3993
02:33:55,969 --> 02:33:53,819
sort of kind of a substrate Independence

3994
02:33:57,530 --> 02:33:55,979
right that that's a that's a kind of

3995
02:34:03,050 --> 02:33:57,540
General class

3996
02:34:04,790 --> 02:34:03,060
much more specific

3997
02:34:07,730 --> 02:34:04,800
realization of it that's called

3998
02:34:09,429 --> 02:34:07,740
computationism that says what's really

3999
02:34:12,610 --> 02:34:09,439
important is to understand

4000
02:34:15,950 --> 02:34:12,620
what computations the system is doing

4001
02:34:18,469 --> 02:34:15,960
where I then understand a computation in

4002
02:34:21,469 --> 02:34:18,479
terms of a turing machine turntable

4003
02:34:23,450 --> 02:34:21,479
right using turrets way of understanding

4004
02:34:26,270 --> 02:34:23,460
a computation okay

4005
02:34:28,910 --> 02:34:26,280
so such a theory would be committed to

4006
02:34:31,429 --> 02:34:28,920
saying that any system

4007
02:34:33,050 --> 02:34:31,439
that there's some calculation or some

4008
02:34:36,469 --> 02:34:33,060
computation

4009
02:34:39,230 --> 02:34:36,479
on some input that can be done such that

4010
02:34:41,450 --> 02:34:39,240
any system doing that computation on

4011
02:34:42,830 --> 02:34:41,460
that input will be conscious in a

4012
02:34:45,110 --> 02:34:42,840
certain way

4013
02:34:47,510 --> 02:34:45,120

all right let's see and again by

4014
02:34:51,050 --> 02:34:47,520
conscious I mean the Paradigm cases of

4015
02:34:53,750 --> 02:34:51,060
is pain right have a toothache right any

4016
02:34:56,770 --> 02:34:53,760
any system that satisfies a certain

4017
02:34:59,750 --> 02:34:56,780
touring table performing a certain

4018
02:35:03,110 --> 02:34:59,760
computation on a certain input will

4019
02:35:04,730 --> 02:35:03,120
experience subjectively a two thing

4020
02:35:07,969 --> 02:35:04,740
and what I have as an argument is that

4021
02:35:11,389 --> 02:35:07,979
that can't be right because you can

4022
02:35:14,090 --> 02:35:11,399
implement the turing machine table

4023
02:35:16,250 --> 02:35:14,100
in Peculiar ways and not ways that

4024
02:35:21,170 --> 02:35:16,260
anybody would actually do in Practical

4025
02:35:24,349 --> 02:35:21,180
life but theoretically you can implement

4026
02:35:26,330 --> 02:35:24,359
a turing machine in ways

4027
02:35:30,230 --> 02:35:26,340
that

4028
02:35:32,389 --> 02:35:30,240
the deterring description depends on a

4029
02:35:33,469 --> 02:35:32,399
bunch of structure that's not physically

4030
02:35:35,510 --> 02:35:33,479
active

4031
02:35:38,570 --> 02:35:35,520
through a certain period it's physically

4032
02:35:41,450 --> 02:35:38,580
completely inert it's not doing anything

4033
02:35:43,429 --> 02:35:41,460
and according to this whether that

4034
02:35:45,889 --> 02:35:43,439
structure is there or not will determine

4035
02:35:47,330 --> 02:35:45,899
whether there's a toothache but on the

4036
02:35:48,889 --> 02:35:47,340
other hand you can see that whether that

4037
02:35:50,929 --> 02:35:48,899
stuff is there or not makes absolutely

4038
02:35:52,490 --> 02:35:50,939

no physical difference to the it makes

4039
02:35:53,690 --> 02:35:52,500
no difference to the physical activity

4040
02:35:57,349 --> 02:35:53,700
going on

4041
02:35:58,849 --> 02:35:57,359
so if you think that the conscious State

4042
02:36:01,610 --> 02:35:58,859
really is determined by physical

4043
02:36:03,710 --> 02:36:01,620
activity it shows that this

4044
02:36:06,290 --> 02:36:03,720
computational

4045
02:36:08,030 --> 02:36:06,300
conceptual apparatus is the wrong one to

4046
02:36:10,010 --> 02:36:08,040
be bringing to you

4047
02:36:12,230 --> 02:36:10,020
but that you can read that paper I mean

4048
02:36:13,969 --> 02:36:12,240
it's a journal philosophy will you be

4049
02:36:15,650 --> 02:36:13,979
able to send me the title of it so I can

4050
02:36:17,330 --> 02:36:15,660
include it in the description it's

4051
02:36:19,790 --> 02:36:17,340
called computation and Consciousness it

4052
02:36:22,250 --> 02:36:19,800
was published in general philosophy

4053
02:36:25,130 --> 02:36:22,260
I mean I could pull up my CV I think

4054
02:36:27,110 --> 02:36:25,140
it's 1989 but you can find it I'll leave

4055
02:36:28,670 --> 02:36:27,120
a link to it in the description so does

4056
02:36:30,650 --> 02:36:28,680
that include

4057
02:36:33,590 --> 02:36:30,660
formulations like integrated information

4058
02:36:35,870 --> 02:36:33,600
Theory that's not well not exactly

4059
02:36:39,230 --> 02:36:35,880
because because as I understand it the

4060
02:36:42,349 --> 02:36:39,240
IIT idea involves

4061
02:36:44,510 --> 02:36:42,359
uh uh information theoretic Concepts

4062
02:36:46,250 --> 02:36:44,520
that go beyond touring the Turing

4063
02:36:48,530 --> 02:36:46,260

description

4064
02:36:51,469 --> 02:36:48,540
but on the other hand I know Scott

4065
02:36:53,030 --> 02:36:51,479
Aronson's criticisms of the IIT and I

4066
02:36:55,429 --> 02:36:53,040
find them completely convincing so I

4067
02:36:57,889 --> 02:36:55,439
don't think the IIT has any more hope

4068
02:37:00,830 --> 02:36:57,899
uh of being an account of Consciousness

4069
02:37:02,330 --> 02:37:00,840
than the term Michigan stuff does have

4070
02:37:04,670 --> 02:37:02,340
you heard of the global neuronal

4071
02:37:07,490 --> 02:37:04,680
workspace Theory

4072
02:37:09,710 --> 02:37:07,500
I the the the the words

4073
02:37:11,809 --> 02:37:09,720
are a little familiar to me but I don't

4074
02:37:13,490 --> 02:37:11,819
know it in a way in any detail to be

4075
02:37:16,250 --> 02:37:13,500
able to comment intelligently about it

4076
02:37:18,290 --> 02:37:16,260
have you heard of yosha Bach yoshibak

4077
02:37:20,270 --> 02:37:18,300
who has his computational

4078
02:37:23,570 --> 02:37:20,280
Consciousness model I don't know what

4079
02:37:25,790 --> 02:37:23,580
it's called uh yeah I'm afraid I'm all

4080
02:37:27,230 --> 02:37:25,800
right don't worry about that okay what

4081
02:37:28,550 --> 02:37:27,240
are your opinions on wolfram's physics

4082
02:37:31,550 --> 02:37:28,560
theory because it's entirely

4083
02:37:32,870 --> 02:37:31,560
computational and seems to at least he

4084
02:37:34,370 --> 02:37:32,880
believes it produces Consciousness

4085
02:37:36,349 --> 02:37:34,380
because we're here and he believes his

4086
02:37:39,830 --> 02:37:36,359
theory to be correct have you taken a

4087
02:37:42,650 --> 02:37:39,840
look into his physics project

4088
02:37:43,690 --> 02:37:42,660

um again not not not in any detail I

4089
02:37:50,030 --> 02:37:43,700
mean

4090
02:37:52,250 --> 02:37:50,040
so I tend to you know anybody who says

4091
02:37:54,230 --> 02:37:52,260
the foundations are computation again it

4092
02:37:56,929 --> 02:37:54,240
seems computation is just the wrong

4093
02:37:58,370 --> 02:37:56,939
concept to be bringing to physics why

4094
02:38:05,150 --> 02:37:58,380
because

4095
02:38:07,370 --> 02:38:05,160
structure they have that they're capable

4096
02:38:08,870 --> 02:38:07,380
of doing the computations that they're

4097
02:38:12,110 --> 02:38:08,880
capable of doing

4098
02:38:13,849 --> 02:38:12,120
that is the physics determines the

4099
02:38:17,030 --> 02:38:13,859
computational structure not the other

4100
02:38:22,570 --> 02:38:19,849
so you know some somebody I mean it it

4101
02:38:26,330 --> 02:38:22,580
it's a bit in the ballpark of

4102
02:38:28,429 --> 02:38:26,340
uh uh uh of again the the idea that

4103
02:38:29,990 --> 02:38:28,439
everything is mathematical right so all

4104
02:38:33,550 --> 02:38:30,000
physical reality is just mathematical

4105
02:38:36,230 --> 02:38:33,560
Max tegmark's idea I just it's so far

4106
02:38:37,969 --> 02:38:36,240
so far off base to me that I don't

4107
02:38:39,889 --> 02:38:37,979
really feel like I need to spend a lot

4108
02:38:41,570 --> 02:38:39,899
of time on them

4109
02:38:43,010 --> 02:38:41,580
you know I think the physical world you

4110
02:38:44,750 --> 02:38:43,020
know I don't know space time it's got

4111
02:38:46,969 --> 02:38:44,760
particles it's got Fields it's got some

4112
02:38:48,469 --> 02:38:46,979
Quantum State trying to understand how

4113
02:38:50,929 --> 02:38:48,479

all that stuff fits together trying to

4114
02:38:53,450 --> 02:38:50,939
figure out what the what the small scale

4115
02:38:56,690 --> 02:38:53,460
geometry of the physical spaces and

4116
02:38:58,630 --> 02:38:56,700
space time and this all strikes me as as

4117
02:39:02,450 --> 02:38:58,640
recognizable

4118
02:39:04,130 --> 02:39:02,460
speculative physics but you go beyond a

4119
02:39:06,770 --> 02:39:04,140
certain point and I don't even recognize

4120
02:39:09,170 --> 02:39:06,780
it as specular

4121
02:39:11,090 --> 02:39:09,180
okay so let's just get to a couple

4122
02:39:13,429 --> 02:39:11,100
questions on time there's entropic time

4123
02:39:15,590 --> 02:39:13,439
and then there's thermal time I don't

4124
02:39:18,170 --> 02:39:15,600
know if those two are the same but what

4125
02:39:20,270 --> 02:39:18,180
are your views on those explanations is

4126
02:39:22,309 --> 02:39:20,280
to the arrow outside I don't I don't I I

4127
02:39:24,170 --> 02:39:22,319
don't even understand I mean again I

4128
02:39:25,730 --> 02:39:24,180
have to just be I don't understand even

4129
02:39:28,210 --> 02:39:25,740
what that means there's time okay

4130
02:39:31,670 --> 02:39:28,220
there's there's a variable we normally

4131
02:39:33,830 --> 02:39:31,680
designated with a t

4132
02:39:36,050 --> 02:39:33,840
um when we assign numbers to it we tend

4133
02:39:39,650 --> 02:39:36,060
to assign numbers so that as

4134
02:39:40,309 --> 02:39:39,660
time goes forward the numbers get larger

4135
02:39:42,530 --> 02:39:40,319
um

4136
02:39:44,090 --> 02:39:42,540
to say that there's entropic time I

4137
02:39:49,190 --> 02:39:44,100
don't even understand what that means I

4138
02:39:53,270 --> 02:39:49,200

mean it's true that if a system is not

4139
02:39:56,150 --> 02:39:53,280
at its entropic maximum it's not thermal

4140
02:39:58,730 --> 02:39:56,160
that typically as time goes forward it

4141
02:40:01,790 --> 02:39:58,740
will become closer to

4142
02:40:02,929 --> 02:40:01,800
thermal equilibrium

4143
02:40:05,389 --> 02:40:02,939
um

4144
02:40:08,150 --> 02:40:05,399
that that

4145
02:40:10,250 --> 02:40:08,160
that's a fact about about and and we

4146
02:40:12,530 --> 02:40:10,260
understand why that's so I mean there's

4147
02:40:16,010 --> 02:40:12,540
pretty good statistical understanding of

4148
02:40:18,230 --> 02:40:16,020
of why as time goes forward entropy

4149
02:40:20,510 --> 02:40:18,240
tends to increase but I don't think that

4150
02:40:22,250 --> 02:40:20,520
means there's a new kind of time there's

4151
02:40:24,889 --> 02:40:22,260
just time

4152
02:40:27,830 --> 02:40:24,899
I think what's being indicated is that

4153
02:40:30,050 --> 02:40:27,840
entropy is the reason for the direction

4154
02:40:31,670 --> 02:40:30,060
of time yeah so I think that's

4155
02:40:34,190 --> 02:40:31,680
completely I mean is that anything that

4156
02:40:36,889 --> 02:40:34,200
makes any I mean look if the universe

4157
02:40:38,750 --> 02:40:36,899
eventually which it it could in some

4158
02:40:42,469 --> 02:40:38,760
models

4159
02:40:44,809 --> 02:40:42,479
if it comes to thermal equilibrium

4160
02:40:47,030 --> 02:40:44,819
and so there's no entropy gradient the

4161
02:40:48,530 --> 02:40:47,040
entropy is just reaches its maximum and

4162
02:40:50,630 --> 02:40:48,540
stays there at least for a very long

4163
02:40:53,270 --> 02:40:50,640

time it's still the case that that the

4164
02:40:56,270 --> 02:40:53,280
time is going from the past to the

4165
02:40:59,210 --> 02:40:56,280
future I mean time will still go on

4166
02:41:03,170 --> 02:40:59,220
why why would anyone think

4167
02:41:05,690 --> 02:41:03,180
that the time would cease to I mean

4168
02:41:07,010 --> 02:41:05,700
the state would constantly be changing I

4169
02:41:09,290 --> 02:41:07,020
mean if you're a thermal equilibrium

4170
02:41:12,550 --> 02:41:09,300
things are still changing right I mean a

4171
02:41:14,750 --> 02:41:12,560
gas in a box comes to equilibrium it's

4172
02:41:17,150 --> 02:41:14,760
microstate is still changing all the

4173
02:41:20,510 --> 02:41:17,160
time and its change is a normal change

4174
02:41:22,790 --> 02:41:20,520
from past to Future and uh the causal

4175
02:41:24,830 --> 02:41:22,800
structure is that is that you know these

4176
02:41:28,190 --> 02:41:24,840
two particles bounced off each other and

4177
02:41:30,230 --> 02:41:28,200
therefore all that goes on even though

4178
02:41:33,290 --> 02:41:30,240
even though there's no entropy gradient

4179
02:41:37,790 --> 02:41:33,300
I mean why would why why would anyone

4180
02:41:40,190 --> 02:41:37,800
even postulate that uh the passage of

4181
02:41:41,870 --> 02:41:40,200
time depends upon an entropy gradient

4182
02:41:44,710 --> 02:41:41,880
it's the other way around

4183
02:41:46,849 --> 02:41:44,720
right the passage of time explains

4184
02:41:48,309 --> 02:41:46,859
together with certain statistical

4185
02:41:51,530 --> 02:41:48,319
considerations

4186
02:41:54,349 --> 02:41:51,540
why typically in a predictably entropy

4187
02:41:56,270 --> 02:41:54,359
goes up if it has a place to go

4188
02:41:57,290 --> 02:41:56,280

up

4189
02:41:59,389 --> 02:41:57,300
um

4190
02:42:01,969 --> 02:41:59,399
but that doesn't make time depend on

4191
02:42:04,670 --> 02:42:01,979
entropy it makes entropy depend on time

4192
02:42:07,490 --> 02:42:04,680
someone that people keep referencing to

4193
02:42:10,370 --> 02:42:07,500
me to look up is Henry bergson and then

4194
02:42:13,010 --> 02:42:10,380
they say that bergson and Bohm

4195
02:42:14,389 --> 02:42:13,020
knew each other or had or or they

4196
02:42:15,650 --> 02:42:14,399
developed their theories together or

4197
02:42:16,849 --> 02:42:15,660
where they were influential to one

4198
02:42:18,830 --> 02:42:16,859
another

4199
02:42:20,450 --> 02:42:18,840
so now that I know that you're an

4200
02:42:22,070 --> 02:42:20,460
extreme bomb fan or at least you're

4201
02:42:24,050 --> 02:42:22,080
you're a proponent of the pilot wave

4202
02:42:26,090 --> 02:42:24,060
theory what are your thoughts on Burks

4203
02:42:28,250 --> 02:42:26,100
and I read I read a book about Burks and

4204
02:42:31,490 --> 02:42:28,260
and Einstein I think you know bergson

4205
02:42:32,870 --> 02:42:31,500
was tremendously confused I I wouldn't I

4206
02:42:35,330 --> 02:42:32,880
wouldn't recommend anybody to spend time

4207
02:42:37,070 --> 02:42:35,340
reading bergson and quite honestly I

4208
02:42:38,510 --> 02:42:37,080
wouldn't recommend anybody spend a lot

4209
02:42:42,710 --> 02:42:38,520
of time reading

4210
02:42:44,270 --> 02:42:42,720
the kinds of things bone wrote in the

4211
02:42:46,070 --> 02:42:44,280
60s when he got involved with

4212
02:42:48,290 --> 02:42:46,080
krishnamurti and he becomes kind of

4213
02:42:50,750 --> 02:42:48,300

semi-mystical and there's the in quick

4214
02:42:53,330 --> 02:42:50,760
inquick order and I mean he wrote a

4215
02:42:56,090 --> 02:42:53,340
bunch of kind of weird stuff

4216
02:43:00,290 --> 02:42:56,100
um you know for you you you you you you

4217
02:43:01,910 --> 02:43:00,300
want to look at his 1952 papers and then

4218
02:43:03,650 --> 02:43:01,920
even better we'll get Belle's

4219
02:43:05,809 --> 02:43:03,660
presentation of the theory which as I

4220
02:43:08,450 --> 02:43:05,819
say bone presents it in terms of a thing

4221
02:43:10,790 --> 02:43:08,460
called a Quantum potential and using

4222
02:43:14,210 --> 02:43:10,800
Newtonian Dynamics and that's a bad idea

4223
02:43:16,429 --> 02:43:14,220
it's not really a Newtonian Theory

4224
02:43:17,990 --> 02:43:16,439
um it's a great Theory okay and it was

4225
02:43:20,450 --> 02:43:18,000
also again a theory that already de

4226
02:43:21,889 --> 02:43:20,460
broily had seen it's the theory is kind

4227
02:43:24,770 --> 02:43:21,899
of

4228
02:43:27,830 --> 02:43:24,780
almost inevitable way to understand

4229
02:43:29,630 --> 02:43:27,840
quantum theory once you ask questions in

4230
02:43:30,410 --> 02:43:29,640
a certain way

4231
02:43:33,410 --> 02:43:30,420
um

4232
02:43:34,670 --> 02:43:33,420
but you know poor boom I mean he got he

4233
02:43:38,030 --> 02:43:34,680
got

4234
02:43:40,730 --> 02:43:38,040
attacked for political reasons in the

4235
02:43:44,630 --> 02:43:40,740
United States kind of exiled to you know

4236
02:43:46,550 --> 02:43:44,640
he had a a life that was you know one of

4237
02:43:48,469 --> 02:43:46,560
being rejected

4238
02:43:50,630 --> 02:43:48,479

having been at Princeton and having

4239
02:43:52,670 --> 02:43:50,640
talked to to Einstein and having been

4240
02:43:54,710 --> 02:43:52,680
influenced by Einstein and then he ends

4241
02:43:57,230 --> 02:43:54,720
up you know in Brazil and then

4242
02:44:00,469 --> 02:43:57,240
eventually at the LSA I have a lot of

4243
02:44:03,650 --> 02:44:00,479
Sympathy for the man as a human being

4244
02:44:05,990 --> 02:44:03,660
um but I think it made him his rejection

4245
02:44:10,010 --> 02:44:06,000
by the physics community

4246
02:44:13,969 --> 02:44:10,020
uh made him more

4247
02:44:16,190 --> 02:44:13,979
open to align with like krishnamurti and

4248
02:44:17,210 --> 02:44:16,200
some people who were of a more mystical

4249
02:44:20,210 --> 02:44:17,220
Bend

4250
02:44:22,490 --> 02:44:20,220
uh and I personally I I don't I don't I

4251
02:44:24,410 --> 02:44:22,500
don't I I don't like I don't see

4252
02:44:27,170 --> 02:44:24,420
anything in that that's helpful helpful

4253
02:44:31,550 --> 02:44:27,180
for for me to do physics

4254
02:44:34,370 --> 02:44:31,560
so I would say study the theory

4255
02:44:36,410 --> 02:44:34,380
um I mean the he he wrote this later

4256
02:44:37,730 --> 02:44:36,420
book called The undivided universe and

4257
02:44:41,030 --> 02:44:37,740
there's some useful things in that

4258
02:44:46,849 --> 02:44:44,210
Holland or not anyway

4259
02:44:49,969 --> 02:44:46,859
um but but I I wouldn't get too wrapped

4260
02:44:51,590 --> 02:44:49,979
up in bone the individual because he was

4261
02:44:53,630 --> 02:44:51,600
he I mean he was quite unless you're

4262
02:44:55,849 --> 02:44:53,640
just interested in it as a personality I

4263
02:44:57,950 --> 02:44:55,859

think a lot of the peculiarities of him

4264
02:44:59,630 --> 02:44:57,960
as a personality don't are not useful

4265
02:45:02,630 --> 02:44:59,640
for understanding physics

4266
02:45:05,690 --> 02:45:02,640
did you ever get to meet Belle sure yeah

4267
02:45:08,570 --> 02:45:05,700
I met him uh three four times

4268
02:45:11,150 --> 02:45:08,580
what was that like oh he's he was just

4269
02:45:14,389 --> 02:45:11,160
he was just the most wonderful human

4270
02:45:16,130 --> 02:45:14,399
being I mean completely unpretentious

4271
02:45:19,130 --> 02:45:16,140
completely open

4272
02:45:21,530 --> 02:45:19,140
completely uh I mean

4273
02:45:23,210 --> 02:45:21,540
I'll tell you a story well I mean I I

4274
02:45:25,490 --> 02:45:23,220
did meet him through and unfortunately

4275
02:45:29,870 --> 02:45:25,500
he was supposed to come to Rutgers when

4276
02:45:31,910 --> 02:45:29,880
I was there uh and he died about a week

4277
02:45:35,450 --> 02:45:31,920
before he was supposed to come which was

4278
02:45:37,370 --> 02:45:35,460
a great tragedy for us but I I met him

4279
02:45:39,410 --> 02:45:37,380
uh at a philosophy of science

4280
02:45:41,270 --> 02:45:39,420
association meeting but not really

4281
02:45:43,490 --> 02:45:41,280
talked to him there I met him in Arisha

4282
02:45:45,410 --> 02:45:43,500
at a meeting and I met him at Rutgers he

4283
02:45:46,670 --> 02:45:45,420
came to Rutgers before and talked to him

4284
02:45:48,469 --> 02:45:46,680
individually

4285
02:45:50,690 --> 02:45:48,479
um but an interesting thing happened

4286
02:45:53,389 --> 02:45:50,700
I'll just tell you a story because it

4287
02:45:56,150 --> 02:45:53,399
it's so much to me Belle the first time

4288
02:45:57,469 --> 02:45:56,160

I heard I mentioned this Girardi Romiti

4289
02:45:59,570 --> 02:45:57,479
Weber Theory

4290
02:46:01,250 --> 02:45:59,580
which is an objective collapse Theory

4291
02:46:03,590 --> 02:46:01,260
and Bell

4292
02:46:07,250 --> 02:46:03,600
has a paper called are there Quantum

4293
02:46:09,770 --> 02:46:07,260
jumps which is again in this book

4294
02:46:10,910 --> 02:46:09,780
um which is his presentation of the grw

4295
02:46:13,309 --> 02:46:10,920
theory

4296
02:46:15,170 --> 02:46:13,319
uh although he goes beyond in certain

4297
02:46:17,990 --> 02:46:15,180
ways what they did

4298
02:46:20,270 --> 02:46:18,000
um but a very nice presentation and the

4299
02:46:23,330 --> 02:46:20,280
first time I heard about that theory was

4300
02:46:25,910 --> 02:46:23,340
from Belle himself it was in oriche

4301
02:46:28,730 --> 02:46:25,920
at this uh NATO summer school

4302
02:46:31,790 --> 02:46:28,740
and I was somebody who grew up

4303
02:46:33,710 --> 02:46:31,800
with the common idea that okay there are

4304
02:46:35,330 --> 02:46:33,720
these collapses of the wave function and

4305
02:46:36,590 --> 02:46:35,340
they're associated with measurements and

4306
02:46:38,510 --> 02:46:36,600
measurements are associated with

4307
02:46:41,030 --> 02:46:38,520
Consciousness this kind of idea you

4308
02:46:43,670 --> 02:46:41,040
associate with with Eugene vigner

4309
02:46:45,349 --> 02:46:43,680
and therefore oh this is amazing this is

4310
02:46:47,690 --> 02:46:45,359
where consciousness

4311
02:46:49,070 --> 02:46:47,700
connects with physics right that

4312
02:46:51,469 --> 02:46:49,080
Consciousness collapses the wave

4313
02:46:53,870 --> 02:46:51,479

function and so on so you think the most

4314
02:46:57,290 --> 02:46:53,880
important question there could be is

4315
02:47:00,710 --> 02:46:57,300
what triggers these collapses

4316
02:47:02,929 --> 02:47:00,720
and Bell presents the grw theory and the

4317
02:47:04,730 --> 02:47:02,939
thing is in that theory nothing triggers

4318
02:47:06,530 --> 02:47:04,740
them they just happen at random with

4319
02:47:08,389 --> 02:47:06,540
fixed probability per unit time per

4320
02:47:10,070 --> 02:47:08,399
particle there's no environmental

4321
02:47:13,010 --> 02:47:10,080
trigger there's no anything they just

4322
02:47:15,710 --> 02:47:13,020
happen okay they just happen at random

4323
02:47:19,130 --> 02:47:15,720
um and and so Bell gives this talk and I

4324
02:47:21,830 --> 02:47:19,140
went up to him afterwards and I said I

4325
02:47:23,450 --> 02:47:21,840
said you're satisfied with this Theory I

4326
02:47:24,830 --> 02:47:23,460
mean here we've been for years and years

4327
02:47:26,389 --> 02:47:24,840
worried about what causes these

4328
02:47:28,790 --> 02:47:26,399
collapses what causes these collapses

4329
02:47:30,830 --> 02:47:28,800
and their answers it just happens and

4330
02:47:33,410 --> 02:47:30,840
and you're happy with that and he just

4331
02:47:36,349 --> 02:47:33,420
he was so mild I mean I can't express to

4332
02:47:39,230 --> 02:47:36,359
you what a nice man he was and he was so

4333
02:47:41,690 --> 02:47:39,240
mild and he just kind of smiled and he

4334
02:47:44,150 --> 02:47:41,700
just looked at me and he said you don't

4335
02:47:47,090 --> 02:47:44,160
appreciate what they've done

4336
02:47:49,550 --> 02:47:47,100
and he was absolutely right and there

4337
02:47:51,950 --> 02:47:49,560
was no point arguing with me at that

4338
02:47:53,750 --> 02:47:51,960

moment but he said exactly the right

4339
02:47:57,889 --> 02:47:53,760
thing

4340
02:48:00,110 --> 02:47:57,899
what they did was they took this idea of

4341
02:48:02,630 --> 02:48:00,120
a collapse and gave it a precise

4342
02:48:07,010 --> 02:48:02,640
mathematical formulation

4343
02:48:09,170 --> 02:48:07,020
and so they turned a notion into an

4344
02:48:11,030 --> 02:48:09,180
actual physical Theory

4345
02:48:12,710 --> 02:48:11,040
whether you like it or not I mean there

4346
02:48:15,410 --> 02:48:12,720
are things about the theory one could

4347
02:48:16,670 --> 02:48:15,420
dislike even Girardi who I got to know

4348
02:48:18,590 --> 02:48:16,680
quite well

4349
02:48:19,790 --> 02:48:18,600
never thought it was a final theory

4350
02:48:23,929 --> 02:48:19,800
always thought it was a kind of

4351
02:48:26,990 --> 02:48:23,939
transition point to a better Theory but

4352
02:48:28,790 --> 02:48:27,000
they managed to just write down some

4353
02:48:30,889 --> 02:48:28,800
equations

4354
02:48:33,910 --> 02:48:30,899
not mentioned measurement not mentioned

4355
02:48:37,309 --> 02:48:33,920
observers and get a theory that gave you

4356
02:48:40,010 --> 02:48:37,319
basically the right predictions

4357
02:48:43,690 --> 02:48:40,020
so Belle was like that and and he didn't

4358
02:48:46,790 --> 02:48:43,700
you know he was just always tremendously

4359
02:48:49,790 --> 02:48:46,800
on point on target

4360
02:48:51,349 --> 02:48:49,800
but he wasn't he just seemed to be the

4361
02:48:55,190 --> 02:48:51,359
nicest person in the world I mean after

4362
02:48:56,870 --> 02:48:55,200
he died there was a there was a eulogy

4363
02:48:58,309 --> 02:48:56,880

session for him at the philosophy of

4364
02:48:59,990 --> 02:48:58,319
science Association I remember Phil

4365
02:49:02,210 --> 02:49:00,000
Pearl who had been working also on

4366
02:49:03,290 --> 02:49:02,220
objective production theories continuous

4367
02:49:06,830 --> 02:49:03,300
ones

4368
02:49:08,090 --> 02:49:06,840
you know he he got up and he said for

4369
02:49:11,690 --> 02:49:08,100
him

4370
02:49:13,309 --> 02:49:11,700
Bell you know for he was somebody Phil

4371
02:49:15,290 --> 02:49:13,319
was somebody working on these

4372
02:49:17,929 --> 02:49:15,300
foundational issues and he said for him

4373
02:49:20,750 --> 02:49:17,939
it was like Belle was kind of a knight

4374
02:49:23,150 --> 02:49:20,760
on a ski to protect them right I mean he

4375
02:49:25,010 --> 02:49:23,160
was the guy they're doing things that

4376
02:49:27,469 --> 02:49:25,020
are very unpopular in the physics

4377
02:49:28,610 --> 02:49:27,479
community and they could always count on

4378
02:49:31,370 --> 02:49:28,620
Belle

4379
02:49:32,809 --> 02:49:31,380
to be there to kind of protect them and

4380
02:49:35,510 --> 02:49:32,819
to say you're doing you know what you're

4381
02:49:37,910 --> 02:49:35,520
doing is important

4382
02:49:40,429 --> 02:49:37,920
um and yeah and you know you think the

4383
02:49:41,809 --> 02:49:40,439
guy I mean he was a very down to earth

4384
02:49:43,309 --> 02:49:41,819
guy he was an engine I'm a century an

4385
02:49:45,170 --> 02:49:43,319
engineer he was designing magnets at

4386
02:49:46,730 --> 02:49:45,180
CERN and he was doing all of this

4387
02:49:49,190 --> 02:49:46,740
foundational work literally on his

4388
02:49:52,070 --> 02:49:49,200

weekends and when he had a sabbatical

4389
02:49:54,230 --> 02:49:52,080
you know he wasn't paid to do it

4390
02:49:57,290 --> 02:49:54,240
but he had

4391
02:49:59,630 --> 02:49:57,300
a a tremendously sharp mind and he had a

4392
02:50:02,150 --> 02:49:59,640
tremendous

4393
02:50:04,010 --> 02:50:02,160
physical intuition right what the

4394
02:50:06,469 --> 02:50:04,020
physical world and Einstein talked about

4395
02:50:08,270 --> 02:50:06,479
having a kind of

4396
02:50:10,309 --> 02:50:08,280
um empathetic understanding of the

4397
02:50:12,770 --> 02:50:10,319
physical world I mean you felt like

4398
02:50:15,230 --> 02:50:12,780
Belle had that he he wasn't satisfied

4399
02:50:17,690 --> 02:50:15,240
with doing a calculation right he wanted

4400
02:50:19,070 --> 02:50:17,700
to understand what was going on you get

4401
02:50:22,010 --> 02:50:19,080
that feeling out of fine when you

4402
02:50:24,710 --> 02:50:22,020
refinement too right that he he just

4403
02:50:26,389 --> 02:50:24,720
driving something mathematically that

4404
02:50:29,270 --> 02:50:26,399
wasn't enough he wanted a picture he

4405
02:50:32,270 --> 02:50:29,280
wanted you know he wanted a feel of what

4406
02:50:34,309 --> 02:50:32,280
the physics was really about

4407
02:50:38,690 --> 02:50:34,319
um and he was just you know a

4408
02:50:40,910 --> 02:50:38,700
tremendously kind and Mild person in

4409
02:50:44,030 --> 02:50:40,920
real life I mean

4410
02:50:46,130 --> 02:50:44,040
you really can't say enough about it

4411
02:50:48,530 --> 02:50:46,140
Professor thank you for spending so much

4412
02:50:52,190 --> 02:50:48,540
time with me

4413
02:50:54,410 --> 02:50:52,200

thank you I mean it's been been fun

4414
02:50:56,150 --> 02:50:54,420
um I hope it was

4415
02:51:00,349 --> 02:50:56,160
more or less what you were looking for

4416
02:51:02,510 --> 02:51:00,359
but it was more it was more thank you

4417
02:51:05,929 --> 02:51:02,520
all right well I do have a side question

4418
02:51:07,969 --> 02:51:05,939
how do you keep your mind Sharp

4419
02:51:09,830 --> 02:51:07,979
you may say well my mind is a sharp it's

4420
02:51:11,630 --> 02:51:09,840
dull but how is it that I don't think

4421
02:51:13,309 --> 02:51:11,640
that you have a dull mind so I imagine

4422
02:51:15,650 --> 02:51:13,319
you have some practice maybe it's

4423
02:51:18,050 --> 02:51:15,660
running maybe it's read maybe you have a

4424
02:51:20,030 --> 02:51:18,060
certain ritual I mean look what I do

4425
02:51:22,790 --> 02:51:20,040
that actually has an influence on that I

4426
02:51:26,090 --> 02:51:22,800
I don't know for sure I mean I I know

4427
02:51:27,889 --> 02:51:26,100
from the little I read that some of the

4428
02:51:29,450 --> 02:51:27,899
things I do like crosswords actually

4429
02:51:32,090 --> 02:51:29,460
don't make any difference all right yeah

4430
02:51:33,050 --> 02:51:32,100
so people say if you do this and this

4431
02:51:35,150 --> 02:51:33,060
and this and then they think well no

4432
02:51:36,830 --> 02:51:35,160
actually and and of course people do say

4433
02:51:38,929 --> 02:51:36,840
that exercise makes a difference and I

4434
02:51:42,650 --> 02:51:38,939
do try to get a reasonable amount of

4435
02:51:45,410 --> 02:51:42,660
exercise maybe that helps I I don't know

4436
02:51:47,389 --> 02:51:45,420
I you know don't have the empirical

4437
02:51:49,309 --> 02:51:47,399
basis to tell you

4438
02:51:51,770 --> 02:51:49,319

there was a question about Judea Pearl

4439
02:51:53,510 --> 02:51:51,780
because he has a book on causation I

4440
02:51:55,250 --> 02:51:53,520
wanted to ask you apparently you have

4441
02:51:56,630 --> 02:51:55,260
some objections to his but if it's too

4442
02:51:58,610 --> 02:51:56,640
long then we'll save it for the next

4443
02:52:00,230 --> 02:51:58,620
time if we speak again yeah I mean look

4444
02:52:02,570 --> 02:52:00,240
it I mean there's a funny thing about

4445
02:52:05,450 --> 02:52:02,580
Pearl if you're interested in Pearl I

4446
02:52:07,370 --> 02:52:05,460
should just mention uh it's relevant to

4447
02:52:13,070 --> 02:52:07,380
understanding

4448
02:52:16,849 --> 02:52:13,080
is it what Pearl's doing is is uh

4449
02:52:19,190 --> 02:52:16,859
is both similar to and was influenced by

4450
02:52:21,769 --> 02:52:19,200
work that my dissertation director Clark

4451
02:52:26,150 --> 02:52:21,779
gleimore did together with Richard

4452
02:52:30,050 --> 02:52:26,160
shyness and Kevin Kelly on on causal on

4453
02:52:30,849 --> 02:52:30,060
causal modeling and and causal discovery

4454
02:52:34,130 --> 02:52:30,859
um

4455
02:52:36,230 --> 02:52:34,140
and uh

4456
02:52:39,830 --> 02:52:36,240
and I just kind of have a feeling that

4457
02:52:43,309 --> 02:52:39,840
that that Pearl gets more attention for

4458
02:52:46,130 --> 02:52:43,319
that relative to what he did and what

4459
02:52:47,030 --> 02:52:46,140
they did that is is warranted

4460
02:52:49,130 --> 02:52:47,040
um

4461
02:52:50,870 --> 02:52:49,140
so I'm a little I mean I'm a little bit

4462
02:52:52,849 --> 02:52:50,880
I don't want to say defensive but I I do

4463
02:52:56,389 --> 02:52:52,859

like if you wanted to look into it you

4464
02:52:57,349 --> 02:52:56,399
should look into gleimore's work

4465
02:53:00,290 --> 02:52:57,359
um

4466
02:53:02,750 --> 02:53:00,300
which was some of it earlier than pearls

4467
02:53:05,389 --> 02:53:02,760
and and again Pearl really learned

4468
02:53:06,950 --> 02:53:05,399
some of the some of the techniques from

4469
02:53:08,630 --> 02:53:06,960
them

4470
02:53:10,730 --> 02:53:08,640
um so it's not a criticism of his work

4471
02:53:12,349 --> 02:53:10,740
it's more about the attribution yeah

4472
02:53:13,730 --> 02:53:12,359
there's a there's a bit of there's a bit

4473
02:53:16,490 --> 02:53:13,740
about attribution

4474
02:53:18,650 --> 02:53:16,500
um there there's some stuff that he does

4475
02:53:20,750 --> 02:53:18,660
in his book if you read I mean I have

4476
02:53:23,269 --> 02:53:20,760
this review of this more popular book

4477
02:53:25,070 --> 02:53:23,279
you probably saw that right in the in

4478
02:53:26,750 --> 02:53:25,080
the Boston Review

4479
02:53:27,830 --> 02:53:26,760
and there is some stuff there that I

4480
02:53:30,530 --> 02:53:27,840
just disagree with it's not the

4481
02:53:32,870 --> 02:53:30,540
technical stuff it's this you know this

4482
02:53:35,510 --> 02:53:32,880
this kind of more hand wavy stuff

4483
02:53:39,650 --> 02:53:35,520
um the technical stuff is just writing

4484
02:53:41,750 --> 02:53:39,660
down causal graphs and uh representing

4485
02:53:44,090 --> 02:53:41,760
various interventions and then seeing

4486
02:53:46,309 --> 02:53:44,100
what kind of Statistics you should you

4487
02:53:48,650 --> 02:53:46,319
should expect in different experimental

4488
02:53:50,269 --> 02:53:48,660

situations uh given different causal

4489
02:53:52,130 --> 02:53:50,279
structures and all that I don't I don't

4490
02:53:56,150 --> 02:53:52,140
have any objection to I mean it's but it

4491
02:53:59,410 --> 02:53:56,160
is very it is the same thing more or

4492
02:54:07,250 --> 02:54:03,469
all right hey thank you again and I I

4493
02:54:10,969 --> 02:54:09,410
the podcast is now finished if you'd

4494
02:54:13,030 --> 02:54:10,979
like to support conversations like this

4495
02:54:14,630 --> 02:54:13,040
then do consider going to

4496
02:54:16,429 --> 02:54:14,640
theoriesofeverything.org it's support

4497
02:54:18,469 --> 02:54:16,439
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