THE UNIVERSE
UNDERSTANDS
ITSELF
DICK
BOND

1
00:00:05,690 --> 00:00:03,889
my name is uh dick Bond uh I'm at the

2
00:00:07,909 --> 00:00:05,700
Canadian Institute for theoretical

3
00:00:10,610 --> 00:00:07,919
astrophysics I'm a theoretical

4
00:00:13,190 --> 00:00:10,620
astrophysicist a cosmologist first and

5
00:00:16,550 --> 00:00:13,200
foremost the theoretical physicists I've

6
00:00:19,130 --> 00:00:16,560
been thinking about these Universal

7
00:00:21,470 --> 00:00:19,140
matters throughout my entire working

8
00:00:23,810 --> 00:00:21,480
career and you could say well even

9
00:00:31,250 --> 00:00:23,820
before because that's what people do you

10
00:00:36,049 --> 00:00:33,470
when did you become first interested in

11
00:00:39,470 --> 00:00:36,059
physics and astronomy probably birth no

12
00:00:42,950 --> 00:00:39,480
uh uh I would say

13
00:00:47,330 --> 00:00:42,960

something that had an impact on me uh

14
00:00:49,850 --> 00:00:47,340
was a book that emerged in the early 50s

15
00:00:53,690 --> 00:00:49,860
uh not that I was reading in the early

16
00:00:57,410 --> 00:00:53,700
50s but it was called I think one two

17
00:00:59,270 --> 00:00:57,420
three Infinity which is a nice by George

18
00:01:02,930 --> 00:00:59,280
gamoff who

19
00:01:06,770 --> 00:01:02,940
um was sort of Mr Big Bang although

20
00:01:10,010 --> 00:01:06,780
Hoyle named it uh and what was so

21
00:01:12,230 --> 00:01:10,020
compelling about it is that he was

22
00:01:12,950 --> 00:01:12,240
trying to

23
00:01:15,830 --> 00:01:12,960
um

24
00:01:18,109 --> 00:01:15,840
take the information they had then on

25
00:01:20,630 --> 00:01:18,119
the universe ban on

26
00:01:22,969 --> 00:01:20,640
formation of Earth geology and all of

27
00:01:26,510 --> 00:01:22,979
that and life for that matter and he

28
00:01:30,289 --> 00:01:26,520
tried to make a synthesis of going from

29
00:01:32,990 --> 00:01:30,299
of basically the beginning through to

30
00:01:34,130 --> 00:01:33,000
the evolution of life on Earth this is

31
00:01:37,130 --> 00:01:34,140
one book

32
00:01:39,410 --> 00:01:37,140
and it was amazing amazing that human

33
00:01:43,069 --> 00:01:39,420
thought could try and

34
00:01:46,069 --> 00:01:43,079
capture this of course we have gone

35
00:01:48,890 --> 00:01:46,079
the large distance from

36
00:01:51,710 --> 00:01:48,900
the information he had back then but on

37
00:01:54,950 --> 00:01:51,720
the other hand he was a very smart guy

38
00:01:57,670 --> 00:01:54,960

and this was uh pretty compelling and

39
00:02:02,450 --> 00:01:57,680
I'm not the only one I was talking to a

40
00:02:05,749 --> 00:02:02,460
uh somebody at uh NYU great Professor

41
00:02:09,229 --> 00:02:05,759
um there and it seems that she I'm the

42
00:02:11,570 --> 00:02:09,239
same era as me had the same uh

43
00:02:14,210 --> 00:02:11,580
Revelation from gamos one two three

44
00:02:17,290 --> 00:02:14,220
infinity and then

45
00:02:20,690 --> 00:02:17,300
it's just understanding the universe

46
00:02:22,610 --> 00:02:20,700
became the thing to be done which is

47
00:02:24,710 --> 00:02:22,620
what every single person on the planet

48
00:02:27,650 --> 00:02:24,720
is trying to do

49
00:02:30,350 --> 00:02:27,660
so I'm just part of that

50
00:02:31,910 --> 00:02:30,360
process do you consider gamma to be not

51
00:02:34,369 --> 00:02:31,920
only a Salient influence on your life

52
00:02:36,470 --> 00:02:34,379
but on your academic background at one

53
00:02:39,170 --> 00:02:36,480
point I wanted to be a writer

54
00:02:41,330 --> 00:02:39,180
uh and then I said

55
00:02:44,570 --> 00:02:41,340
to myself uh

56
00:02:48,350 --> 00:02:44,580
you can't write without knowing what the

57
00:02:51,830 --> 00:02:48,360
Leading Edge of human thought is on uh

58
00:02:53,630 --> 00:02:51,840
reality if you like and that anybody

59
00:02:55,490 --> 00:02:53,640
who's writing without

60
00:02:58,009 --> 00:02:55,500
being there

61
00:03:00,410 --> 00:02:58,019
is writing something which will

62
00:03:02,030 --> 00:03:00,420
maybe we'll have things like emotional

63
00:03:05,030 --> 00:03:02,040

truth and other such things but it

64
00:03:06,710 --> 00:03:05,040
cannot be a correct statement not that

65
00:03:09,050 --> 00:03:06,720
what the students are reading now are

66
00:03:12,890 --> 00:03:09,060
correct anyway so what I did is I sort

67
00:03:16,910 --> 00:03:12,900
of shot my bow from that period And The

68
00:03:19,130 --> 00:03:16,920
Arc of my career has been exactly the

69
00:03:22,750 --> 00:03:19,140
attempt to do this kind of full

70
00:03:26,750 --> 00:03:22,760
integration of thinking and trying to

71
00:03:30,350 --> 00:03:26,760
take science which means knowledge and

72
00:03:34,490 --> 00:03:30,360
apply it to the the thing that really

73
00:03:38,149 --> 00:03:34,500
matters to me which is the eye that is

74
00:03:39,890 --> 00:03:38,159
to say the science is the way to try and

75
00:03:42,170 --> 00:03:39,900
comprehend one's

76
00:03:43,729 --> 00:03:42,180
self and the place in the universe which

77
00:03:47,930 --> 00:03:43,739
is not an easy thing to do and most

78
00:03:51,110 --> 00:03:47,940
people uh have Minds that are split into

79
00:03:53,809 --> 00:03:51,120
a lot of channels and many of the

80
00:03:56,809 --> 00:03:53,819
channels don't talk to each other but a

81
00:03:58,990 --> 00:03:56,819
goal ultimately is to integrate and now

82
00:04:03,050 --> 00:03:59,000
that I'm of an age

83
00:04:05,030 --> 00:04:03,060
39 or so actually this but that's the

84
00:04:07,610 --> 00:04:05,040
Jack Benny thing right

85
00:04:08,869 --> 00:04:07,620
um that I feel that I'm at the situation

86
00:04:11,710 --> 00:04:08,879
where

87
00:04:15,050 --> 00:04:11,720
I've got to take the leap and try and

88
00:04:17,150 --> 00:04:15,060

integrate all of the ideas of which I

89
00:04:20,330 --> 00:04:17,160
have traveled over many in my career

90
00:04:22,909 --> 00:04:20,340
it's always been with his goal but now

91
00:04:24,950 --> 00:04:22,919
I've decided I have license to go crazy

92
00:04:26,270 --> 00:04:24,960
do you believe that science is The

93
00:04:28,010 --> 00:04:26,280
Cutting Edge

94
00:04:34,850 --> 00:04:28,020
it is

95
00:04:37,550 --> 00:04:34,860
the modus operandi for uh humans to

96
00:04:40,670 --> 00:04:37,560
understand and see the universe and that

97
00:04:42,469 --> 00:04:40,680
it was the great development I mean I

98
00:04:45,950 --> 00:04:42,479
can go back to

99
00:04:49,310 --> 00:04:45,960
definitely the Greeks the pre-greeks uh

100
00:04:52,850 --> 00:04:49,320
through the whole uh period of the

101
00:04:54,890 --> 00:04:52,860
Renaissance and in particular there is

102
00:04:56,110 --> 00:04:54,900
that period that is called The Age of

103
00:04:58,730 --> 00:04:56,120
Reason

104
00:04:59,930 --> 00:04:58,740
we have now entered into the age of

105
00:05:02,330 --> 00:04:59,940
unreason

106
00:05:06,010 --> 00:05:02,340
in the world around us although

107
00:05:08,270 --> 00:05:06,020
everything is trying to

108
00:05:11,770 --> 00:05:08,280
unify with

109
00:05:14,810 --> 00:05:11,780
everybody communicating with information

110
00:05:17,450 --> 00:05:14,820
uh and the information flood is kind of

111
00:05:19,969 --> 00:05:17,460
overwhelming and it does split into

112
00:05:23,090 --> 00:05:19,979
streams and we see this manifested all

113
00:05:26,390 --> 00:05:23,100

around us but what should be at the core

114
00:05:29,870 --> 00:05:26,400
is the basic quest for knowledge which

115
00:05:32,510 --> 00:05:29,880
is the Quest for science so science is

116
00:05:36,170 --> 00:05:32,520
then transcending just physics or

117
00:05:39,650 --> 00:05:36,180
chemistry or biology it is at the heart

118
00:05:41,450 --> 00:05:39,660
of uh humanity and what how people

119
00:05:43,790 --> 00:05:41,460
should be operating those to say you

120
00:05:47,029 --> 00:05:43,800
want knowledge and you want to apply

121
00:05:49,490 --> 00:05:47,039
knowledge to the world around us what's

122
00:05:51,409 --> 00:05:49,500
meant by the term universe

123
00:05:54,830 --> 00:05:51,419
well that's an interesting question

124
00:05:57,590 --> 00:05:54,840
because what is often put out there is

125
00:05:59,570 --> 00:05:57,600
the word which I am not that fond of

126
00:06:01,370 --> 00:05:59,580
although many of my friends like to use

127
00:06:04,610 --> 00:06:01,380
it the Multiverse

128
00:06:07,850 --> 00:06:04,620
there is only universe that's what the

129
00:06:10,790 --> 00:06:07,860
uni is in front it's the one and then

130
00:06:13,730 --> 00:06:10,800
the question is how complex is it but it

131
00:06:17,210 --> 00:06:13,740
is all that there is basically by

132
00:06:20,570 --> 00:06:17,220
definition the thing that is very

133
00:06:22,610 --> 00:06:20,580
humbling if you like the universe seems

134
00:06:26,689 --> 00:06:22,620
vast the one the part that we can see

135
00:06:29,990 --> 00:06:26,699
but the way we think of it now is that

136
00:06:32,090 --> 00:06:30,000
what we see is only a tiny part of a

137
00:06:35,090 --> 00:06:32,100
much much greater whole then the

138
00:06:36,830 --> 00:06:35,100

question is is it all connected or are

139
00:06:38,870 --> 00:06:36,840
there disconnected elements well if it

140
00:06:39,890 --> 00:06:38,880
is a completely disconnected element we

141
00:06:42,290 --> 00:06:39,900
could never know about it because

142
00:06:45,670 --> 00:06:42,300
there's no communication uh the things

143
00:06:48,590 --> 00:06:45,680
that are beyond the speed of light reach

144
00:06:50,110 --> 00:06:48,600
we don't get information on the only way

145
00:06:53,090 --> 00:06:50,120
we can get that information

146
00:06:56,090 --> 00:06:53,100
is by looking

147
00:06:58,730 --> 00:06:56,100
around us in the universe

148
00:07:02,809 --> 00:06:58,740
try understand how the patterns have

149
00:07:06,230 --> 00:07:02,819
developed and then say I'll go back to

150
00:07:08,090 --> 00:07:06,240
one two three Infinity you then say that

151
00:07:11,510 --> 00:07:08,100
this applies to the region that you

152
00:07:14,210 --> 00:07:11,520
cannot see that of course uh is

153
00:07:16,610 --> 00:07:14,220
impossible to get right really

154
00:07:19,850 --> 00:07:16,620
but on the other hand

155
00:07:24,969 --> 00:07:19,860
um it is clear that the themes that we

156
00:07:28,249 --> 00:07:24,979
see around us and out to the

157
00:07:30,350 --> 00:07:28,259
observable edge of the universe uh there

158
00:07:32,570 --> 00:07:30,360
is a commonality I mean that is an

159
00:07:35,930 --> 00:07:32,580
amazing thing right that you know you

160
00:07:38,629 --> 00:07:35,940
don't go into some area of the universe

161
00:07:40,730 --> 00:07:38,639
which is drastically different I mean it

162
00:07:46,309 --> 00:07:40,740
in time it's different because it

163
00:07:49,610 --> 00:07:46,319

evolves but uh it isn't like uh at least

164
00:07:51,290 --> 00:07:49,620
in the patch that we can see that there

165
00:07:54,409 --> 00:07:51,300
is a coherence

166
00:07:57,050 --> 00:07:54,419
the coherence is essential basically but

167
00:07:59,689 --> 00:07:57,060
for me I don't really see why there

168
00:08:02,749 --> 00:07:59,699
should be coherence

169
00:08:06,290 --> 00:08:02,759
I mean coherence writ really large that

170
00:08:08,749 --> 00:08:06,300
is to say everything connected in fact

171
00:08:12,969 --> 00:08:08,759
one of the things that I'm

172
00:08:15,830 --> 00:08:12,979
known for is uh of label the cosmic web

173
00:08:19,749 --> 00:08:15,840
which of course web means something to

174
00:08:25,070 --> 00:08:19,759
everybody because of the um internet web

175
00:08:28,010 --> 00:08:25,080
but uh what that word caught or those

176
00:08:31,490 --> 00:08:28,020
words Cosmic web indicate is the

177
00:08:33,529 --> 00:08:31,500
interconnectivity of everything and that

178
00:08:35,149 --> 00:08:33,539
every aspect of the universe is

179
00:08:38,630 --> 00:08:35,159
connected with every answer that's sort

180
00:08:41,089 --> 00:08:38,640
of cliche and obvious but it's also

181
00:08:43,969 --> 00:08:41,099
incredibly profound it means that

182
00:08:46,970 --> 00:08:43,979
everything is dressed in the

183
00:08:50,509 --> 00:08:46,980
interactions with everything else and uh

184
00:08:54,430 --> 00:08:50,519
in particular it's writ large in the

185
00:09:00,470 --> 00:08:54,440
universe that we can see uh but for me

186
00:09:03,410 --> 00:09:00,480
the universe is beyond that and uh one

187
00:09:04,370 --> 00:09:03,420
way you can think about this is

188
00:09:07,509 --> 00:09:04,380

um

189
00:09:10,130 --> 00:09:07,519
I don't want to get into the

190
00:09:12,710 --> 00:09:10,140
concept of the universe of simulation

191
00:09:13,910 --> 00:09:12,720
although that's an interesting point but

192
00:09:17,210 --> 00:09:13,920
uh

193
00:09:19,910 --> 00:09:17,220
in a sense we think of the universe as a

194
00:09:21,590 --> 00:09:19,920
realization of reality

195
00:09:24,850 --> 00:09:21,600
and then

196
00:09:29,150 --> 00:09:24,860
we think there can be a lot of realities

197
00:09:31,490 --> 00:09:29,160
and at some level quantum mechanics

198
00:09:33,829 --> 00:09:31,500
has those uh

199
00:09:36,590 --> 00:09:33,839
realities interacting with each other

200
00:09:38,810 --> 00:09:36,600
because uh

201
00:09:40,009 --> 00:09:38,820
the quantum theory

202
00:09:42,710 --> 00:09:40,019
uh

203
00:09:45,170 --> 00:09:42,720
is one of its basic elements is that

204
00:09:48,170 --> 00:09:45,180
information diffuses which means that

205
00:09:50,509 --> 00:09:48,180
you don't you cannot over concentrate

206
00:09:52,550 --> 00:09:50,519
information so it flows out I mean

207
00:09:55,550 --> 00:09:52,560
that's a manifestation of that is things

208
00:09:58,190 --> 00:09:55,560
like the hydrogen atom Etc where you

209
00:10:01,850 --> 00:09:58,200
don't have the electric charge right at

210
00:10:03,889 --> 00:10:01,860
the center on top of the proton the

211
00:10:05,509 --> 00:10:03,899
uncertainty aspects of the universe

212
00:10:08,449 --> 00:10:05,519
enforce

213
00:10:11,690 --> 00:10:08,459

through this kind of interaction that

214
00:10:13,670 --> 00:10:11,700
it's got you know on ground state I'm

215
00:10:15,829 --> 00:10:13,680
maybe going too far here but it's got a

216
00:10:17,630 --> 00:10:15,839
ground state structure

217
00:10:18,949 --> 00:10:17,640
um and uh you know that's manifested

218
00:10:21,829 --> 00:10:18,959
everywhere that there are these

219
00:10:25,190 --> 00:10:21,839
structures that occur and one aspect of

220
00:10:29,090 --> 00:10:25,200
the structure is uh uh information

221
00:10:30,829 --> 00:10:29,100
trying to propagate from whatever the

222
00:10:34,130 --> 00:10:30,839
origin is to

223
00:10:36,530 --> 00:10:34,140
uh throughout the Universe I mean that

224
00:10:39,410 --> 00:10:36,540
sort of one of the main themes that I

225
00:10:42,470 --> 00:10:39,420
work on in in what I do research on that

226
00:10:45,050 --> 00:10:42,480
was a long way from what is universe but

227
00:10:47,389 --> 00:10:45,060
in fact it isn't because it's in my view

228
00:10:50,150 --> 00:10:47,399
at the heart of universe regarding

229
00:10:52,490 --> 00:10:50,160
complex structure how does it arise you

230
00:10:55,130 --> 00:10:52,500
know we have a mantra and the Mantra has

231
00:10:57,290 --> 00:10:55,140
been in place from well actually you

232
00:11:00,110 --> 00:10:57,300
could really trace it to

233
00:11:03,650 --> 00:11:00,120
um around 1980 or so but maybe even a

234
00:11:08,690 --> 00:11:03,660
bit before but not well formed then

235
00:11:10,790 --> 00:11:08,700
which is that uh the the that there is

236
00:11:13,069 --> 00:11:10,800
something fundamental which we believe

237
00:11:16,550 --> 00:11:13,079
is happening all around us

238
00:11:19,730 --> 00:11:16,560

something that we work with all of the

239
00:11:22,009 --> 00:11:19,740
time everything is built upon it we call

240
00:11:24,829 --> 00:11:22,019
it the vacuum which sounds like it's

241
00:11:27,710 --> 00:11:24,839
nothing but in fact the vacuum is like

242
00:11:32,690 --> 00:11:27,720
everything and that'll probably become

243
00:11:34,730 --> 00:11:32,700
clearer as I uh say more but within the

244
00:11:37,610 --> 00:11:34,740
vacuum there are these fluctuations are

245
00:11:40,329 --> 00:11:37,620
often called virtual fluctuations what

246
00:11:44,690 --> 00:11:40,339
does it mean to be virtual it means that

247
00:11:46,269 --> 00:11:44,700
humans aren't seeing it but if you take

248
00:11:49,310 --> 00:11:46,279
the vacuum

249
00:11:51,170 --> 00:11:49,320
and bend it then you get observable

250
00:11:53,990 --> 00:11:51,180
consequences and one of the observable

251
00:11:55,550 --> 00:11:54,000
consequences is all of the structure in

252
00:11:59,150 --> 00:11:55,560
the universe or at least that's the

253
00:12:01,850 --> 00:11:59,160
current picture and so uh and it's a

254
00:12:03,949 --> 00:12:01,860
picture which is so compelling it's one

255
00:12:06,370 --> 00:12:03,959
of the reasons I put so much energy into

256
00:12:10,310 --> 00:12:06,380
trying to understand the concept of

257
00:12:13,970 --> 00:12:10,320
deformed vacua which is so anyway the

258
00:12:16,550 --> 00:12:13,980
basic picture and these fluctuations are

259
00:12:18,490 --> 00:12:16,560
happening all around us and you know at

260
00:12:22,130 --> 00:12:18,500
some level all of your structures

261
00:12:25,130 --> 00:12:22,140
yourself is built upon that underlying

262
00:12:29,449 --> 00:12:25,140
structure of this what you might call

263
00:12:33,590 --> 00:12:29,459

vast sea of fluctuations that exist and

264
00:12:36,949 --> 00:12:33,600
that all of phenomenal reality is played

265
00:12:41,290 --> 00:12:36,959
on top of that here it's like a huge C

266
00:12:44,210 --> 00:12:41,300
and here we're sort of you know uh

267
00:12:46,850 --> 00:12:44,220
sailing along the surface of that sea

268
00:12:50,449 --> 00:12:46,860
and we don't know how deep the sea is we

269
00:12:52,670 --> 00:12:50,459
don't know how far the vacuum goes uh

270
00:12:56,569 --> 00:12:52,680
it may go

271
00:12:58,790 --> 00:12:56,579
I doubt anything goes to Infinity but

272
00:13:03,949 --> 00:12:58,800
um uh it could

273
00:13:03,959 --> 00:13:06,769
uh

274
00:13:14,210 --> 00:13:10,150
anyway so the vacuum is fundamental

275
00:13:15,590 --> 00:13:14,220
fluctuations that are like virtually I

276
00:13:18,410 --> 00:13:15,600
mean people think of it as virtual

277
00:13:20,750 --> 00:13:18,420
particles so you think of charges like

278
00:13:22,910 --> 00:13:20,760
plus and minus plus and minus always

279
00:13:25,250 --> 00:13:22,920
appearing but that they don't actually

280
00:13:27,829 --> 00:13:25,260
break apart from each other so that you

281
00:13:31,610 --> 00:13:27,839
actually can observe in your detector A

282
00:13:35,650 --> 00:13:31,620
Plus or a minus they're kind of always

283
00:13:38,470 --> 00:13:35,660
oscillating and blending but the same

284
00:13:41,269 --> 00:13:38,480
aspect is that that's kind of a

285
00:13:44,449 --> 00:13:41,279
so-called fermion picture where there's

286
00:13:47,030 --> 00:13:44,459
uh well I I actually don't want to get

287
00:13:49,430 --> 00:13:47,040
heavily unless we go there eventually

288
00:13:52,190 --> 00:13:49,440

into fermions and bosons we probably

289
00:13:55,430 --> 00:13:52,200
will but maybe not at this point in the

290
00:13:58,670 --> 00:13:55,440
conversation uh anyway the basic Mantra

291
00:14:02,569 --> 00:13:58,680
is quantum fluctuations but that isn't

292
00:14:05,150 --> 00:14:02,579
the important issue that may exist is

293
00:14:06,470 --> 00:14:05,160
fundamental that they condense and

294
00:14:11,210 --> 00:14:06,480
freeze out

295
00:14:14,449 --> 00:14:11,220
and freeze in patterns of density

296
00:14:18,230 --> 00:14:14,459
fluctuations gravitational potential

297
00:14:19,490 --> 00:14:18,240
fluctuations those things are what

298
00:14:21,530 --> 00:14:19,500
ultimately

299
00:14:24,410 --> 00:14:21,540
grows to make all of the complex

300
00:14:27,170 --> 00:14:24,420
structure of the universe so we have a

301
00:14:30,110 --> 00:14:27,180
what is in effect a relatively

302
00:14:31,790 --> 00:14:30,120
Simple Theory I mean it's ridiculous

303
00:14:34,430 --> 00:14:31,800
that we think we can think about it

304
00:14:36,710 --> 00:14:34,440
which is you know the first 10 to the

305
00:14:41,090 --> 00:14:36,720
minus 33 seconds of the universe and all

306
00:14:44,710 --> 00:14:41,100
of that but we do and it just seems like

307
00:14:47,930 --> 00:14:44,720
home those thoughts right and the

308
00:14:51,290 --> 00:14:47,940
consequences are everything

309
00:14:54,110 --> 00:14:51,300
and we actually think we can observe

310
00:14:56,050 --> 00:14:54,120
them through the impact on things like

311
00:14:59,030 --> 00:14:56,060
the cosmic microwave background the

312
00:15:02,030 --> 00:14:59,040
photon Afterglow the big bang and and

313
00:15:04,730 --> 00:15:02,040

many other things so we have a a theory

314
00:15:07,370 --> 00:15:04,740
where we can make observations Here and

315
00:15:11,150 --> 00:15:07,380
Now on Earth large-scale structure of

316
00:15:13,189 --> 00:15:11,160
the universe and uh interpret what we

317
00:15:16,009 --> 00:15:13,199
think is going on at these unimaginably

318
00:15:18,410 --> 00:15:16,019
Early times and part of that is because

319
00:15:20,509 --> 00:15:18,420
what was happening at those unimaginally

320
00:15:23,449 --> 00:15:20,519
Early times at least in the region that

321
00:15:24,470 --> 00:15:23,459
we can see seems to have been relatively

322
00:15:26,930 --> 00:15:24,480
simple

323
00:15:30,230 --> 00:15:26,940
we're looking for

324
00:15:32,870 --> 00:15:30,240
more complexity in what emerged from the

325
00:15:34,970 --> 00:15:32,880
ultra early Universe because that would

326
00:15:36,410 --> 00:15:34,980
give us more information but right at

327
00:15:39,410 --> 00:15:36,420
the moment the amount of information

328
00:15:40,910 --> 00:15:39,420
we're getting is we're essentially

329
00:15:43,069 --> 00:15:40,920
compressing

330
00:15:45,230 --> 00:15:43,079
all of the information in the ultra

331
00:15:47,090 --> 00:15:45,240
Universe into what is in effect two

332
00:15:50,750 --> 00:15:47,100
numbers it's hard to believe but that's

333
00:15:53,509 --> 00:15:50,760
the story I mean that is the general

334
00:15:57,050 --> 00:15:53,519
point about structure information then

335
00:15:59,150 --> 00:15:57,060
as the universe evolves uh

336
00:16:02,509 --> 00:15:59,160
species emerge

337
00:16:03,730 --> 00:16:02,519
I'm not unlike in evolution a biological

338
00:16:06,410 --> 00:16:03,740

evolution

339
00:16:08,569 --> 00:16:06,420
so there may be some kind of grand

340
00:16:10,069 --> 00:16:08,579
unification soup which I think is

341
00:16:11,629 --> 00:16:10,079
probably correct

342
00:16:13,670 --> 00:16:11,639
uh

343
00:16:16,550 --> 00:16:13,680
inflationary energy and I know you want

344
00:16:18,910 --> 00:16:16,560
to get to this eventually that is to say

345
00:16:22,610 --> 00:16:18,920
what is called dark energy

346
00:16:25,090 --> 00:16:22,620
that that's like this kind of universal

347
00:16:29,389 --> 00:16:25,100
coherent energy

348
00:16:32,210 --> 00:16:29,399
that uh splits up into what is

349
00:16:34,069 --> 00:16:32,220
ultimately all of the species of the

350
00:16:36,530 --> 00:16:34,079
universe and then it and then the

351
00:16:40,670 --> 00:16:36,540
universe passes through various epics

352
00:16:43,249 --> 00:16:40,680
where certain of those species are more

353
00:16:45,949 --> 00:16:43,259
important than in other times species

354
00:16:48,370 --> 00:16:45,959
come and species go and we're dealing

355
00:16:51,710 --> 00:16:48,380
with some kind of fossil

356
00:16:53,689 --> 00:16:51,720
Relic which is a non-trivial one because

357
00:16:55,970 --> 00:16:53,699
it's what makes us up

358
00:16:58,310 --> 00:16:55,980
can you explain how the universe expands

359
00:17:00,110 --> 00:16:58,320
and what's meant by it

360
00:17:02,509 --> 00:17:00,120
contrary to

361
00:17:05,270 --> 00:17:02,519
popular view it's true that on large

362
00:17:06,470 --> 00:17:05,280
scales the universe around us is

363
00:17:12,490 --> 00:17:06,480

expanding

364
00:17:14,169 --> 00:17:12,500
it's in an effectively a state of

365
00:17:16,970 --> 00:17:14,179
equilibrium

366
00:17:18,829 --> 00:17:16,980
and so and galaxies and other such

367
00:17:21,530 --> 00:17:18,839
things form

368
00:17:23,210 --> 00:17:21,540
there is no expansion associated with

369
00:17:25,130 --> 00:17:23,220
that this is a good thing otherwise we

370
00:17:29,270 --> 00:17:25,140
would all be getting fatter because in

371
00:17:34,310 --> 00:17:32,150
on the large scales very large scales

372
00:17:37,250 --> 00:17:34,320
there's an expansion the expansion is

373
00:17:39,470 --> 00:17:37,260
characterized by a rate of expansion uh

374
00:17:41,810 --> 00:17:39,480
it's called the Hubble parameter I'm

375
00:17:43,549 --> 00:17:41,820
sure you've heard of it which is

376
00:17:46,490 --> 00:17:43,559
basically just the expansion rate of the

377
00:17:48,430 --> 00:17:46,500
universe but you can also think of it as

378
00:17:50,930 --> 00:17:48,440
spatially

379
00:17:52,190 --> 00:17:50,940
dependent and so in our region of the

380
00:17:54,950 --> 00:17:52,200
universe

381
00:17:57,850 --> 00:17:54,960
our galaxy here

382
00:18:00,789 --> 00:17:57,860
there is effectively

383
00:18:04,370 --> 00:18:00,799
no uniform

384
00:18:06,169 --> 00:18:04,380
expansion or contraction there is a an

385
00:18:07,850 --> 00:18:06,179
equilibrium it's not a true equilibrium

386
00:18:09,650 --> 00:18:07,860
because everything is always changing in

387
00:18:11,990 --> 00:18:09,660
time it's just a question of how slowly

388
00:18:13,730 --> 00:18:12,000

or how fast it's changing

389
00:18:14,570 --> 00:18:13,740
but

390
00:18:19,130 --> 00:18:14,580
um

391
00:18:20,810 --> 00:18:19,140
anyway dynamical Universe uh and now I'm

392
00:18:22,909 --> 00:18:20,820
losing the threat of where we were

393
00:18:24,350 --> 00:18:22,919
trying to go basically because I was

394
00:18:27,289 --> 00:18:24,360
going someplace so I was trying to give

395
00:18:30,830 --> 00:18:27,299
you a way of looking at the universe

396
00:18:32,930 --> 00:18:30,840
that is actually not standard but if I

397
00:18:34,730 --> 00:18:32,940
had to look around me which if I can I

398
00:18:36,610 --> 00:18:34,740
will

399
00:18:38,930 --> 00:18:36,620
this is a

400
00:18:39,830 --> 00:18:38,940
undergraduate student who's working with

401
00:18:45,650 --> 00:18:39,840
me

402
00:18:48,230 --> 00:18:45,660
thermal history of the universe as it

403
00:18:49,970 --> 00:18:48,240
starts at the beginning and goes through

404
00:18:52,070 --> 00:18:49,980
various phases I know you're going to

405
00:18:55,370 --> 00:18:52,080
ask this question later but I thought

406
00:18:59,270 --> 00:18:55,380
thanks for arranging my Prof

407
00:19:01,130 --> 00:18:59,280
and here were four points about what we

408
00:19:05,390 --> 00:19:01,140
were going to do she's still engaged

409
00:19:08,210 --> 00:19:05,400
with this with me and one of them is the

410
00:19:11,330 --> 00:19:08,220
H naught tension which has gotten a lot

411
00:19:13,250 --> 00:19:11,340
of press recently because from the

412
00:19:14,750 --> 00:19:13,260
cosmic microwave background which is

413
00:19:16,130 --> 00:19:14,760

this really high Precision thing that

414
00:19:18,110 --> 00:19:16,140
I've been very much engaged with

415
00:19:21,289 --> 00:19:18,120
throughout my entire career

416
00:19:23,090 --> 00:19:21,299
uh we get a certain value of how rapidly

417
00:19:25,250 --> 00:19:23,100
on large scales the universe is

418
00:19:29,150 --> 00:19:25,260
expanding on average

419
00:19:32,630 --> 00:19:29,160
and then there are other claims using

420
00:19:35,210 --> 00:19:32,640
things like Supernova and stars of a

421
00:19:38,270 --> 00:19:35,220
specific form that the value is

422
00:19:40,970 --> 00:19:38,280
different in the

423
00:19:44,029 --> 00:19:40,980
quite in general Cosmic neighborhood

424
00:19:48,650 --> 00:19:44,039
around us this is called the H naught

425
00:19:52,250 --> 00:19:48,660
tension the expansion rate tension and

426
00:19:55,310 --> 00:19:52,260
it's the number of meetings about this

427
00:19:57,169 --> 00:19:55,320
is enormous around the world and the

428
00:19:58,909 --> 00:19:57,179
issue is whether it's a systematic

429
00:20:01,190 --> 00:19:58,919
effect of not understanding the data

430
00:20:03,890 --> 00:20:01,200
well enough or whether there is some new

431
00:20:06,230 --> 00:20:03,900
profound thing associated with something

432
00:20:10,730 --> 00:20:06,240
that happened relatively late

433
00:20:13,130 --> 00:20:10,740
that cause this expansion to change

434
00:20:16,130 --> 00:20:13,140
we already know that the expansion is

435
00:20:18,770 --> 00:20:16,140
changing in fact that was part of the

436
00:20:20,230 --> 00:20:18,780
great discovery of What's called the

437
00:20:23,570 --> 00:20:20,240
dark energy

438
00:20:24,950 --> 00:20:23,580

but it may be that there is a different

439
00:20:28,570 --> 00:20:24,960
expansion

440
00:20:31,669 --> 00:20:28,580
in the area around us

441
00:20:35,570 --> 00:20:31,679
out to a fairly large distance and then

442
00:20:38,210 --> 00:20:35,580
on even larger distances so uh this is a

443
00:20:41,210 --> 00:20:38,220
puzzle and why did I do this I was just

444
00:20:43,250 --> 00:20:41,220
trying to say that there is a simple way

445
00:20:46,549 --> 00:20:43,260
of thinking about

446
00:20:47,810 --> 00:20:46,559
the evolution of the universe uh as long

447
00:20:49,250 --> 00:20:47,820
as you

448
00:20:51,770 --> 00:20:49,260
add

449
00:20:53,090 --> 00:20:51,780
position as well as time into how you

450
00:20:56,330 --> 00:20:53,100
think about it and that it's

451
00:20:59,029 --> 00:20:56,340
inhomogeneous and that it's the same

452
00:21:02,510 --> 00:20:59,039
basic language but it is rarely used

453
00:21:04,250 --> 00:21:02,520
that way in the subject which uh

454
00:21:06,590 --> 00:21:04,260
one of my missions even with

455
00:21:07,970 --> 00:21:06,600
undergraduates is to teach that way of

456
00:21:10,850 --> 00:21:07,980
looking at things

457
00:21:12,770 --> 00:21:10,860
what is dark energy

458
00:21:14,529 --> 00:21:12,780
dark energy

459
00:21:17,049 --> 00:21:14,539
well it

460
00:21:19,250 --> 00:21:17,059
emerged as

461
00:21:27,049 --> 00:21:19,260
so-called Einstein's cosmological

462
00:21:30,890 --> 00:21:27,059
constant and um uh back in 1917 or so

463
00:21:33,110 --> 00:21:30,900

uh the observations were such that there

464
00:21:36,169 --> 00:21:33,120
was no indication a that there was

465
00:21:39,049 --> 00:21:36,179
clearly external galaxies and so it

466
00:21:41,990 --> 00:21:39,059
seemed like the stars and structure they

467
00:21:45,110 --> 00:21:42,000
were just buzzing around us so that on

468
00:21:48,950 --> 00:21:45,120
average it was an equilibrium situation

469
00:21:51,470 --> 00:21:48,960
and so yet when you take the laws of

470
00:21:52,370 --> 00:21:51,480
gravity Einstein's theory curiously

471
00:21:53,930 --> 00:21:52,380
enough

472
00:21:57,370 --> 00:21:53,940
um

473
00:22:00,289 --> 00:21:57,380
it would either contract or expand

474
00:22:02,870 --> 00:22:00,299
automatically the contraction is called

475
00:22:05,570 --> 00:22:02,880
gravitational instability and it's the

476
00:22:07,090 --> 00:22:05,580
way we understand how structure formed

477
00:22:09,710 --> 00:22:07,100
in the universe it's the gravitational

478
00:22:10,730 --> 00:22:09,720
instability theory of the formation of

479
00:22:13,610 --> 00:22:10,740
structure

480
00:22:16,430 --> 00:22:13,620
and so he said well you know maybe the

481
00:22:17,990 --> 00:22:16,440
data is going to enforce me so I'm going

482
00:22:20,570 --> 00:22:18,000
to put in a term

483
00:22:23,570 --> 00:22:20,580
which the theory allowed

484
00:22:26,750 --> 00:22:23,580
and uh it's called the cosmological

485
00:22:29,630 --> 00:22:26,760
constant and then uh about a decade

486
00:22:33,350 --> 00:22:29,640
later or so somebody proved that that

487
00:22:36,169 --> 00:22:33,360
theory is unstable as well and uh and

488
00:22:38,810 --> 00:22:36,179

Hubble discovered the expansion of the

489
00:22:41,029 --> 00:22:38,820
universe by looking at galaxies nearby

490
00:22:46,010 --> 00:22:41,039
and how they were moving away

491
00:22:49,909 --> 00:22:46,020
and um and I you know this uh famous

492
00:22:52,010 --> 00:22:49,919
statement of Einsteins that uh it was

493
00:22:54,049 --> 00:22:52,020
the biggest blunder he never apparently

494
00:22:56,330 --> 00:22:54,059
actually said that and it wasn't a

495
00:22:58,610 --> 00:22:56,340
blunder it's at sort of the heart of

496
00:23:02,630 --> 00:22:58,620
much of our thinking because one way of

497
00:23:05,510 --> 00:23:02,640
thinking about it is that it's the um

498
00:23:08,750 --> 00:23:05,520
energy density of the vacuum and are

499
00:23:10,010 --> 00:23:08,760
going back to the word vacuum so when I

500
00:23:14,450 --> 00:23:10,020
write it

501
00:23:17,930 --> 00:23:14,460
I often use row as density many people

502
00:23:20,990 --> 00:23:17,940
use Rover density sub vac

503
00:23:25,430 --> 00:23:21,000
as if that's an obvious thing vacuum

504
00:23:27,529 --> 00:23:25,440
energy except that as I said earlier in

505
00:23:34,430 --> 00:23:27,539
this uh

506
00:23:39,230 --> 00:23:37,549
the vacuum is fundamentally deformed

507
00:23:41,330 --> 00:23:39,240
it's deformed by the expansion of the

508
00:23:43,130 --> 00:23:41,340
universe it's formed by structure

509
00:23:46,909 --> 00:23:43,140
deformed by structures in the universe

510
00:23:50,750 --> 00:23:46,919
so vacuum is not actually

511
00:23:53,630 --> 00:23:50,760
um this pristine thing that people think

512
00:23:56,810 --> 00:23:53,640
about anyway the bottom line is that

513
00:24:00,049 --> 00:23:56,820

that was the original Lambda and it was

514
00:24:04,010 --> 00:24:00,059
embraced by if I won't go into the full

515
00:24:07,310 --> 00:24:04,020
history of this uh but it would rise up

516
00:24:10,310 --> 00:24:07,320
and go down and rise up and go down in

517
00:24:14,770 --> 00:24:10,320
terms of its stock if you like go vote

518
00:24:17,990 --> 00:24:14,780
whether people were interested in it uh

519
00:24:21,350 --> 00:24:18,000
it kind of got resurrected for a few

520
00:24:24,830 --> 00:24:21,360
reasons around the mid 80s

521
00:24:30,430 --> 00:24:24,840
and that's when I was I thought it was

522
00:24:34,370 --> 00:24:30,440
you know a great idea why because uh

523
00:24:36,950 --> 00:24:34,380
as well as matter and radiation

524
00:24:39,649 --> 00:24:36,960
uh

525
00:24:41,750 --> 00:24:39,659
the universe can have curvature I mean

526
00:24:43,789 --> 00:24:41,760
in fact it's always got curvature on

527
00:24:46,850 --> 00:24:43,799
small scales that's what

528
00:24:50,270 --> 00:24:46,860
causes the matter to concentrate anyway

529
00:24:53,750 --> 00:24:50,280
the basic point is that there was this

530
00:24:55,549 --> 00:24:53,760
first indication for me that you needed

531
00:24:57,830 --> 00:24:55,559
something akin to a Lambda the reason I

532
00:25:01,130 --> 00:24:57,840
uh going back to the threat of thought

533
00:25:04,549 --> 00:25:01,140
there uh curving the Universe on average

534
00:25:06,890 --> 00:25:04,559
on large scales and yet having small

535
00:25:09,230 --> 00:25:06,900
fluctuations on smaller skills and we

536
00:25:10,730 --> 00:25:09,240
had evidence for that anyway the basic

537
00:25:13,430 --> 00:25:10,740
point is you have to have this

538
00:25:15,890 --> 00:25:13,440

large-scale curvature if you're going to

539
00:25:19,669 --> 00:25:15,900
have what is called an open or closed

540
00:25:23,750 --> 00:25:19,679
Universe uh whether it's curve

541
00:25:26,990 --> 00:25:23,760
up like a sphere or curve down like a

542
00:25:30,409 --> 00:25:27,000
saddle uh that was you know what people

543
00:25:32,630 --> 00:25:30,419
mostly thought about whereas the vacuum

544
00:25:34,430 --> 00:25:32,640
energy density

545
00:25:36,830 --> 00:25:34,440
um is something that's constant and

546
00:25:37,970 --> 00:25:36,840
scale independent or at least that's the

547
00:25:39,470 --> 00:25:37,980
view

548
00:25:42,049 --> 00:25:39,480
uh

549
00:25:44,990 --> 00:25:42,059
so then the other dilemma occurred well

550
00:25:48,529 --> 00:25:45,000
how can it be as small as it would need

551
00:25:51,110 --> 00:25:48,539
to be to make a universe like ours

552
00:25:53,510 --> 00:25:51,120
and that continues to be a huge mystery

553
00:25:57,169 --> 00:25:53,520
because if you count

554
00:25:59,810 --> 00:25:57,179
the the amount of energy density that

555
00:26:02,090 --> 00:25:59,820
you think is in the vacuum it would

556
00:26:04,010 --> 00:26:02,100
depend upon the

557
00:26:05,630 --> 00:26:04,020
Planck energy scale

558
00:26:08,570 --> 00:26:05,640
in fact it would go like the fourth

559
00:26:11,630 --> 00:26:08,580
power which is a huge huge number like

560
00:26:13,970 --> 00:26:11,640
nothing that we have ever seen except

561
00:26:16,789 --> 00:26:13,980
the key element here is that you don't

562
00:26:19,850 --> 00:26:16,799
apparently get to observe that you only

563
00:26:22,370 --> 00:26:19,860

get to observe differences or changes

564
00:26:24,110 --> 00:26:22,380
and so maybe it can all be well

565
00:26:27,409 --> 00:26:24,120
understood that way

566
00:26:34,970 --> 00:26:30,890
anyway so I liked Lambda

567
00:26:40,490 --> 00:26:34,980
I liked it as a extension Beyond

568
00:26:42,830 --> 00:26:40,500
um just dark matter and uh and baryons

569
00:26:46,310 --> 00:26:42,840
which are the stuff that we're made of

570
00:26:48,950 --> 00:26:46,320
uh and uh

571
00:26:52,310 --> 00:26:48,960
and so it became part of my kind of

572
00:26:56,450 --> 00:26:52,320
standard thing and then

573
00:26:57,289 --> 00:26:56,460
we were dealing with two kinds of data

574
00:26:59,690 --> 00:26:57,299
um

575
00:27:02,810 --> 00:26:59,700
Cosmic microwave background as it was

576
00:27:05,390 --> 00:27:02,820
emerging fluctuations that emerge from

577
00:27:08,570 --> 00:27:05,400
the universe around

578
00:27:09,950 --> 00:27:08,580
uh 380 000 years after the so-called Big

579
00:27:10,549 --> 00:27:09,960
Bang

580
00:27:14,149 --> 00:27:10,559
um

581
00:27:15,049 --> 00:27:14,159
and that's like 13.8 billion years ago

582
00:27:17,810 --> 00:27:15,059
um

583
00:27:20,110 --> 00:27:17,820
so that was giving us valuable

584
00:27:23,890 --> 00:27:20,120
information it's since filled in

585
00:27:27,470 --> 00:27:23,900
brilliantly but you know as it emerged

586
00:27:30,890 --> 00:27:27,480
uh it was giving us an indication but

587
00:27:33,769 --> 00:27:30,900
you had we had to add large-scale

588
00:27:35,810 --> 00:27:33,779

structure to that the spatial

589
00:27:39,710 --> 00:27:35,820
inhomogeneity on large scales of the

590
00:27:41,570 --> 00:27:39,720
universe in order to say it looks like

591
00:27:43,310 --> 00:27:41,580
Lambda is pretty good

592
00:27:45,350 --> 00:27:43,320
and we did

593
00:27:47,510 --> 00:27:45,360
and then so that was microwave

594
00:27:49,549 --> 00:27:47,520
background and um

595
00:27:53,090 --> 00:27:49,559
and uh

596
00:27:55,909 --> 00:27:53,100
large-scale structure observations uh

597
00:27:59,870 --> 00:27:55,919
then another set of groups they were

598
00:28:02,750 --> 00:27:59,880
looking at Supernova and they were

599
00:28:05,450 --> 00:28:02,760
developing something curiously enough

600
00:28:08,029 --> 00:28:05,460
it's called the Hubble diagram where

601
00:28:11,930 --> 00:28:08,039
it's Hubble parameter is a function of

602
00:28:13,970 --> 00:28:11,940
time and uh if you have an ordinary

603
00:28:16,370 --> 00:28:13,980
Universe without any Lambda it would

604
00:28:19,370 --> 00:28:16,380
have a certain shape and with Lambda it

605
00:28:21,370 --> 00:28:19,380
has a different shape and so

606
00:28:26,090 --> 00:28:21,380
after

607
00:28:28,330 --> 00:28:26,100
some stops and starts uh it emerged that

608
00:28:31,010 --> 00:28:28,340
that looked like it was also indicating

609
00:28:33,110 --> 00:28:31,020
uh accelerated expansion and that's the

610
00:28:34,909 --> 00:28:33,120
one that uh

611
00:28:36,830 --> 00:28:34,919
sort of

612
00:28:39,710 --> 00:28:36,840
became the popular way of understanding

613
00:28:41,210 --> 00:28:39,720

of how this emerged but in the microwave

614
00:28:43,850 --> 00:28:41,220
background large scale structure were

615
00:28:46,610 --> 00:28:43,860
right there as the underfinning of this

616
00:28:48,230 --> 00:28:46,620
whole story and then uh there's another

617
00:28:50,390 --> 00:28:48,240
experiment that I was involved in it's

618
00:28:50,990 --> 00:28:50,400
called boomerang

619
00:28:53,330 --> 00:28:51,000
um

620
00:28:55,490 --> 00:28:53,340
it was a microwave background experiment

621
00:28:56,870 --> 00:28:55,500
called Boomerang because you launched

622
00:28:59,330 --> 00:28:56,880
from the

623
00:29:01,970 --> 00:28:59,340
uh Antarctica

624
00:29:04,430 --> 00:29:01,980
and uh the prevailing winds at the top

625
00:29:06,950 --> 00:29:04,440
of the atmosphere caused the balloon to

626
00:29:08,710 --> 00:29:06,960
go around and around and around and so

627
00:29:12,890 --> 00:29:08,720
you get lots of data

628
00:29:15,590 --> 00:29:12,900
and it was really the thing that sold

629
00:29:17,810 --> 00:29:15,600
the vast community in particular the

630
00:29:20,090 --> 00:29:17,820
particle theorists on that you have to

631
00:29:23,389 --> 00:29:20,100
take this extremely seriously it's like

632
00:29:26,810 --> 00:29:23,399
uh that that that's clearly the answer

633
00:29:27,710 --> 00:29:26,820
then the issue is what is the nature of

634
00:29:30,350 --> 00:29:27,720
this

635
00:29:33,350 --> 00:29:30,360
so-called Dark Energy I mean what does

636
00:29:34,610 --> 00:29:33,360
it mean to say an energy is dark for

637
00:29:38,090 --> 00:29:34,620
that matter

638
00:29:39,529 --> 00:29:38,100

this is not this is a bit of a joke for

639
00:29:42,049 --> 00:29:39,539
that matter

640
00:29:45,110 --> 00:29:42,059
why do we call it dark matter

641
00:29:46,870 --> 00:29:45,120
and why since matter and energy are

642
00:29:50,389 --> 00:29:46,880
intimately related

643
00:29:52,250 --> 00:29:50,399
why do we have this stupid label but we

644
00:29:54,409 --> 00:29:52,260
do that in this subject there's stupid

645
00:29:56,870 --> 00:29:54,419
labels all over the place some actually

646
00:30:00,529 --> 00:29:56,880
quite clever but you know up down

647
00:30:02,269 --> 00:30:00,539
strange charm is is particle theory

648
00:30:04,370 --> 00:30:02,279
right so if you know there's a little

649
00:30:06,909 --> 00:30:04,380
Whimsy that does occur but Dark Energy

650
00:30:11,330 --> 00:30:06,919
really doesn't convey the information

651
00:30:13,970 --> 00:30:11,340
it's actually uh uh potential energy

652
00:30:16,310 --> 00:30:13,980
density that at the moment we observe

653
00:30:19,850 --> 00:30:16,320
only through its impact on the expansion

654
00:30:23,090 --> 00:30:19,860
of the universe and not uh in any direct

655
00:30:26,870 --> 00:30:23,100
experimental way the hope is that we

656
00:30:29,630 --> 00:30:26,880
will be able to and so you know billions

657
00:30:31,490 --> 00:30:29,640
of dollars actually have been put into

658
00:30:34,070 --> 00:30:31,500
experiments

659
00:30:36,049 --> 00:30:34,080
that give huge amounts of astronomical

660
00:30:40,490 --> 00:30:36,059
information but one of their primary

661
00:30:43,310 --> 00:30:40,500
result was to learn more about the dark

662
00:30:45,830 --> 00:30:43,320
energy which you cannot learn

663
00:30:50,570 --> 00:30:45,840

from observations on the earth in the

664
00:30:52,190 --> 00:30:50,580
lab it is really something writ large in

665
00:30:56,510 --> 00:30:52,200
the ultra large scale Dynamics in the

666
00:31:01,370 --> 00:30:56,520
universe anyway it emerged as being an

667
00:31:03,529 --> 00:31:01,380
ingredient and as time went on it got uh

668
00:31:05,149 --> 00:31:03,539
the the observational evidence got

669
00:31:07,549 --> 00:31:05,159
stronger and stronger and stronger that

670
00:31:11,090 --> 00:31:07,559
that was it and so there were two

671
00:31:15,169 --> 00:31:11,100
aspects to this one is is it just a

672
00:31:18,289 --> 00:31:15,179
uniform potential energy density so that

673
00:31:19,370 --> 00:31:18,299
everywhere including in this robe there

674
00:31:21,169 --> 00:31:19,380
would be

675
00:31:23,570 --> 00:31:21,179
this uh

676
00:31:25,730 --> 00:31:23,580
uniform energy density that's sitting

677
00:31:29,149 --> 00:31:25,740
there you wouldn't really be feeling it

678
00:31:32,510 --> 00:31:29,159
but if it could it would try and expand

679
00:31:35,149 --> 00:31:32,520
you it's just that the other forces are

680
00:31:39,409 --> 00:31:35,159
so strong that that doesn't happen

681
00:31:43,549 --> 00:31:39,419
um anyway so there's uh uh this kind of

682
00:31:46,190 --> 00:31:43,559
uniform energy density that uh we think

683
00:31:48,350 --> 00:31:46,200
is you know all pervasive but the

684
00:31:50,510 --> 00:31:48,360
evidence we have a phora is on very

685
00:31:53,750 --> 00:31:50,520
large scales so then the question is

686
00:31:55,610 --> 00:31:53,760
does it change in time and why is that

687
00:31:58,909 --> 00:31:55,620
interesting it's because it says it

688
00:32:01,370 --> 00:31:58,919

might not just be potential energy it

689
00:32:03,470 --> 00:32:01,380
might also have a kinetic component you

690
00:32:05,510 --> 00:32:03,480
know there are two types when you learn

691
00:32:09,169 --> 00:32:05,520
physics in school there's potential

692
00:32:12,409 --> 00:32:09,179
energy and kinetic energy and so what is

693
00:32:14,990 --> 00:32:12,419
the kinetic energy amount of the dart

694
00:32:18,010 --> 00:32:15,000
associated with the dark energy so this

695
00:32:22,130 --> 00:32:18,020
is a blazing question and as I said

696
00:32:23,990 --> 00:32:22,140
we're trying very hard to determine

697
00:32:25,490 --> 00:32:24,000
whether or not that's needed at the

698
00:32:29,269 --> 00:32:25,500
moment it isn't

699
00:32:33,049 --> 00:32:29,279
uh and yet some people say you'll never

700
00:32:36,950 --> 00:32:33,059
find it because it's uniform it's got to

701
00:32:39,590 --> 00:32:36,960
be uniform and I don't ascribe to that I

702
00:32:42,590 --> 00:32:39,600
think that it can change the thing that

703
00:32:46,549 --> 00:32:42,600
to my mind is the most interesting is if

704
00:32:49,610 --> 00:32:46,559
the dark energy actually interacts with

705
00:32:53,389 --> 00:32:49,620
ordinary matter and dark matter

706
00:32:56,630 --> 00:32:53,399
so that it can have a spatial dependence

707
00:32:59,690 --> 00:32:56,640
not a sharp spatial dependence but a

708
00:33:01,549 --> 00:32:59,700
spatial dependence that can allow us to

709
00:33:04,190 --> 00:33:01,559
determine more about it because

710
00:33:06,230 --> 00:33:04,200
otherwise all we get is a number what's

711
00:33:07,070 --> 00:33:06,240
the balance between matter and dark

712
00:33:13,750 --> 00:33:07,080
matter

713
00:33:17,990 --> 00:33:13,760

here in our galaxy holding it together

714
00:33:20,149 --> 00:33:18,000
but we don't think that we have a very

715
00:33:21,529 --> 00:33:20,159
high concentration we do would have a

716
00:33:23,750 --> 00:33:21,539
concentration but not a very high

717
00:33:25,789 --> 00:33:23,760
concentration of dark matter in this

718
00:33:28,970 --> 00:33:25,799
room with this relative to the rest of

719
00:33:31,130 --> 00:33:28,980
everything else everything has its

720
00:33:34,930 --> 00:33:31,140
structural aspect and it's all

721
00:33:38,990 --> 00:33:34,940
describable in detail by

722
00:33:42,110 --> 00:33:39,000
the laws of Transport in the universe

723
00:33:44,450 --> 00:33:42,120
um something that I am very keen about

724
00:33:47,090 --> 00:33:44,460
because it's an issue of how does energy

725
00:33:50,570 --> 00:33:47,100
go from one place to another

726
00:33:54,710 --> 00:33:50,580
it's uh and evolution is all associated

727
00:33:56,870 --> 00:33:54,720
with transport and so the transport of

728
00:33:59,950 --> 00:33:56,880
very owns ordinary matter is different

729
00:34:03,289 --> 00:33:59,960
than the transport of dark matter and

730
00:34:06,350 --> 00:34:03,299
the transport of dark energy seems to be

731
00:34:08,930 --> 00:34:06,360
particularly simple but hopefully not so

732
00:34:11,089 --> 00:34:08,940
simple that we can't learn more about it

733
00:34:15,950 --> 00:34:11,099
than just a single number

734
00:34:18,790 --> 00:34:15,960
so uh and so all of this is in this mix

735
00:34:22,129 --> 00:34:18,800
or this soup of ingredients

736
00:34:24,169 --> 00:34:22,139
and um I think this is one of the points

737
00:34:28,190 --> 00:34:24,179
you want to get to later so jump into it

738
00:34:31,310 --> 00:34:28,200

now and actually go back to my prop here

739
00:34:33,230 --> 00:34:31,320
which is uh the history of the universe

740
00:34:36,470 --> 00:34:33,240
the so-called thermal history of the

741
00:34:39,889 --> 00:34:36,480
universe starting with

742
00:34:43,190 --> 00:34:39,899
this very high density which is

743
00:34:45,889 --> 00:34:43,200
the inflationary epic it's the idea is

744
00:34:48,050 --> 00:34:45,899
that it was fluctuation this year that

745
00:34:52,070 --> 00:34:48,060
ultimately led to structure

746
00:34:55,369 --> 00:34:52,080
then there is a point at which that

747
00:34:58,430 --> 00:34:55,379
incredible coherence breaks up

748
00:35:00,650 --> 00:34:58,440
that a colleague who's actually just in

749
00:35:03,950 --> 00:35:00,660
the office next door and I we coined the

750
00:35:07,010 --> 00:35:03,960
phrase a shock in time so that you have

751
00:35:10,190 --> 00:35:07,020
this Universal accelerated expansion

752
00:35:13,810 --> 00:35:10,200
which is the dark energy of its time

753
00:35:16,790 --> 00:35:13,820
culturally universe but then it kind of

754
00:35:21,530 --> 00:35:16,800
shatter isn't the word but it

755
00:35:24,130 --> 00:35:21,540
uh shocks and becomes all of these kind

756
00:35:26,230 --> 00:35:24,140
of fluctuations like

757
00:35:29,390 --> 00:35:26,240
photons and

758
00:35:32,630 --> 00:35:29,400
electrons positrons and

759
00:35:36,170 --> 00:35:32,640
all of the normal quarks and hadrons and

760
00:35:38,750 --> 00:35:36,180
other things that have to arise from our

761
00:35:43,069 --> 00:35:38,760
uh you know our observations show it our

762
00:35:45,170 --> 00:35:43,079
resistance shows it uh and that is a

763
00:35:48,950 --> 00:35:45,180

period in which the density changes

764
00:35:50,690 --> 00:35:48,960
that's uh a period in which radiation

765
00:35:54,349 --> 00:35:50,700
dominates and there are a number of

766
00:35:57,770 --> 00:35:54,359
epochs that are associated with that uh

767
00:35:59,089 --> 00:35:57,780
there is the so-called hadronic era

768
00:36:03,410 --> 00:35:59,099
which is

769
00:36:05,450 --> 00:36:03,420
um the uh period where you haven't

770
00:36:06,349 --> 00:36:05,460
formed

771
00:36:10,370 --> 00:36:06,359
um

772
00:36:12,470 --> 00:36:10,380
that it's primarily a quark gluon plasma

773
00:36:15,410 --> 00:36:12,480
which means that the quarks haven't

774
00:36:17,990 --> 00:36:15,420
really you know uh completely gone into

775
00:36:21,109 --> 00:36:18,000
neutrons and protons and then you have

776
00:36:23,630 --> 00:36:21,119
all of these which layer become mesons

777
00:36:25,069 --> 00:36:23,640
all of these so so-called gluons which

778
00:36:28,990 --> 00:36:25,079
are the glue that holds them together

779
00:36:32,089 --> 00:36:29,000
and the gluons uh and the quarks

780
00:36:34,490 --> 00:36:32,099
they're all relativistic and have this

781
00:36:37,849 --> 00:36:34,500
large density you see I'm speaking as if

782
00:36:40,190 --> 00:36:37,859
this is an absolutely obvious stated uh

783
00:36:42,609 --> 00:36:40,200
you know from above we had these tablets

784
00:36:44,870 --> 00:36:42,619
in it and that is not true everything

785
00:36:45,950 --> 00:36:44,880
that one thinks about the elderly

786
00:36:47,870 --> 00:36:45,960
universe

787
00:36:49,430 --> 00:36:47,880
you know there could be the rug pulled

788
00:36:52,130 --> 00:36:49,440

out from under us or maybe a different

789
00:36:55,190 --> 00:36:52,140
way of thinking about it but the

790
00:36:57,890 --> 00:36:55,200
evidence is amazing for the story of

791
00:37:00,410 --> 00:36:57,900
cosmic Evolution so we have gone through

792
00:37:03,650 --> 00:37:00,420
to the uh

793
00:37:06,890 --> 00:37:03,660
the uh Quirk era but then they the

794
00:37:09,710 --> 00:37:06,900
quartz and luans but then they basically

795
00:37:12,530 --> 00:37:09,720
freeze out first into one that's

796
00:37:14,829 --> 00:37:12,540
dominated by mesons as well as neutrons

797
00:37:18,710 --> 00:37:14,839
and protons but the neutrons and protons

798
00:37:21,349 --> 00:37:18,720
are uh sort of small ingredients

799
00:37:23,810 --> 00:37:21,359
relative to the total I know you want to

800
00:37:26,150 --> 00:37:23,820
get to this question as well so we'll

801
00:37:28,550 --> 00:37:26,160
get there don't worry it's nice that I

802
00:37:30,250 --> 00:37:28,560
have my prop though

803
00:37:32,630 --> 00:37:30,260
um and

804
00:37:35,270 --> 00:37:32,640
there is a period in which you

805
00:37:37,970 --> 00:37:35,280
transition from a basically free quarks

806
00:37:39,890 --> 00:37:37,980
and gluons that are all in some what's

807
00:37:42,650 --> 00:37:39,900
called a plasma

808
00:37:47,050 --> 00:37:42,660
not unlike the plasmas that we're used

809
00:37:48,770 --> 00:37:47,060
to with the electrons and ions Etc

810
00:37:53,750 --> 00:37:48,780
and

811
00:37:56,510 --> 00:37:53,760
then it becomes hydronic which means

812
00:37:58,130 --> 00:37:56,520
that you s because of the expansion of

813
00:38:01,569 --> 00:37:58,140

the universe you've moved things far

814
00:38:04,849 --> 00:38:01,579
enough apart that

815
00:38:05,530 --> 00:38:04,859
forces caused

816
00:38:12,470 --> 00:38:05,540
um

817
00:38:14,089 --> 00:38:12,480
different masses to form ultimately as

818
00:38:16,790 --> 00:38:14,099
the universe continues to expand those

819
00:38:18,650 --> 00:38:16,800
annihilate and that leaves behind the

820
00:38:21,770 --> 00:38:18,660
protons and the neutrons

821
00:38:24,109 --> 00:38:21,780
there's still a huge amount and most of

822
00:38:26,410 --> 00:38:24,119
the energy is in electrons and protons

823
00:38:29,210 --> 00:38:26,420
and neutrinos and photons

824
00:38:31,730 --> 00:38:29,220
and that is what is called the lepton

825
00:38:34,130 --> 00:38:31,740
air of the Big Bang or at least used to

826
00:38:37,790 --> 00:38:34,140
be called that I mean to me it's just a

827
00:38:41,589 --> 00:38:37,800
continuous situation and that is the

828
00:38:44,530 --> 00:38:41,599
period at around a minute in which

829
00:38:49,310 --> 00:38:44,540
hydrogen and helium

830
00:38:52,210 --> 00:38:49,320
nuclei uh get the patterns they do so

831
00:38:56,329 --> 00:38:52,220
there's uh it's called Big Bang

832
00:38:59,810 --> 00:38:56,339
nucleosynthesis nucleo for nuclear and

833
00:39:04,190 --> 00:38:59,820
uh the reactions that occur

834
00:39:07,550 --> 00:39:04,200
create the Light Elements mostly helium

835
00:39:09,470 --> 00:39:07,560
and and hydrogen remains and so most of

836
00:39:13,069 --> 00:39:09,480
the universe is hydrogen and helium

837
00:39:14,630 --> 00:39:13,079
there's some deuterium and you don't get

838
00:39:17,930 --> 00:39:14,640

very much

839
00:39:20,870 --> 00:39:17,940
almost none carbon and oxygen and iron

840
00:39:24,349 --> 00:39:20,880
or anything like that that is delayed

841
00:39:26,810 --> 00:39:24,359
until the formation of stars and you

842
00:39:28,430 --> 00:39:26,820
forge those in the nuclear furnaces of

843
00:39:30,050 --> 00:39:28,440
the stars and then you have to explode

844
00:39:33,250 --> 00:39:30,060
things and blow them out

845
00:39:35,810 --> 00:39:33,260
so we're passing through these epics

846
00:39:38,870 --> 00:39:35,820
this thermal history

847
00:39:41,810 --> 00:39:38,880
and so we've gone through this dominance

848
00:39:45,589 --> 00:39:41,820
of relativistic particles

849
00:39:48,530 --> 00:39:45,599
so here it was dominated by what was you

850
00:39:53,030 --> 00:39:48,540
might call it Ultra early dark energy

851
00:40:00,589 --> 00:39:53,040
then we have uh this period of dominance

852
00:40:05,690 --> 00:40:04,130
there is a an epic uh

853
00:40:08,390 --> 00:40:05,700
well maybe a hundred thousand years

854
00:40:11,750 --> 00:40:08,400
after the big bang where you begin to

855
00:40:13,609 --> 00:40:11,760
transition to the dominance of matter

856
00:40:15,650 --> 00:40:13,619
which is non-relatives like that's when

857
00:40:19,550 --> 00:40:15,660
the protons and the neutrons in the dark

858
00:40:21,770 --> 00:40:19,560
matter basically take over the dominant

859
00:40:26,210 --> 00:40:21,780
things in the expansion

860
00:40:27,650 --> 00:40:26,220
and that's also when the photons

861
00:40:30,230 --> 00:40:27,660
decouple

862
00:40:33,530 --> 00:40:30,240
the word decoupling is something I may

863
00:40:37,250 --> 00:40:33,540

use later as the universe expands

864
00:40:42,230 --> 00:40:37,260
various things at various times decouple

865
00:40:44,450 --> 00:40:42,240
and extremely important one is when the

866
00:40:46,390 --> 00:40:44,460
Cosmic microwave background the photon

867
00:40:50,870 --> 00:40:46,400
Afterglow of the Big Bang

868
00:40:52,430 --> 00:40:50,880
basically stop strongly interacting with

869
00:40:57,109 --> 00:40:52,440
the electrons

870
00:40:59,990 --> 00:40:57,119
and so they can split apart and we

871
00:41:02,089 --> 00:41:00,000
observe the residue of that and the

872
00:41:04,550 --> 00:41:02,099
cosmic background radiation

873
00:41:07,490 --> 00:41:04,560
thank you for this prop as well

874
00:41:11,089 --> 00:41:07,500
this was uh from the so-called uh

875
00:41:15,650 --> 00:41:11,099
Wilkinson microwave anisotropy probe the

876
00:41:17,690 --> 00:41:15,660
beach ball it shows uh the

877
00:41:19,810 --> 00:41:17,700
tiny fluctuations in the microwave

878
00:41:23,030 --> 00:41:19,820
background from which we learned so much

879
00:41:26,690 --> 00:41:23,040
and this is basically trying to be a

880
00:41:29,750 --> 00:41:26,700
snapshot of the way the universe was

881
00:41:30,890 --> 00:41:29,760
uh 380 000 years at the big bank now

882
00:41:32,510 --> 00:41:30,900
there are other effects that are

883
00:41:35,569 --> 00:41:32,520
occurring but that's the dominant thing

884
00:41:38,510 --> 00:41:35,579
and since I'm showing you this

885
00:41:41,329 --> 00:41:38,520
which is wmap which I was somewhat

886
00:41:42,710 --> 00:41:41,339
associated with I cannot resist but to

887
00:41:44,329 --> 00:41:42,720
show

888
00:41:47,329 --> 00:41:44,339

uh

889
00:41:50,630 --> 00:41:47,339
the plank satellite because it was an

890
00:41:52,670 --> 00:41:50,640
early version of Planck as we were

891
00:41:55,490 --> 00:41:52,680
taking all of this stuff in front of it

892
00:41:58,130 --> 00:41:55,500
and these are the fluctuations Planck is

893
00:42:00,770 --> 00:41:58,140
still the best experiment of the best

894
00:42:02,390 --> 00:42:00,780
information and I've been in not

895
00:42:05,510 --> 00:42:02,400
involved in that a long time and it's

896
00:42:09,170 --> 00:42:05,520
the best indicator for launder

897
00:42:11,870 --> 00:42:09,180
that the cosmological constant anyway uh

898
00:42:15,010 --> 00:42:11,880
so that's this period

899
00:42:17,870 --> 00:42:15,020
of dominance by non-relativistic matter

900
00:42:21,290 --> 00:42:17,880
and with the photons having propagated

901
00:42:23,150 --> 00:42:21,300
it up that was essential for the

902
00:42:25,849 --> 00:42:23,160
structure to start collapsing and

903
00:42:29,150 --> 00:42:25,859
forming and allowing the ability for

904
00:42:32,690 --> 00:42:29,160
galaxies and ultimately planets to form

905
00:42:35,810 --> 00:42:32,700
you had to get it out of the a

906
00:42:39,290 --> 00:42:35,820
dominance by um

907
00:42:42,650 --> 00:42:39,300
dark energy and B out of the dominance

908
00:42:46,490 --> 00:42:42,660
of radiation in order for a structure to

909
00:42:47,870 --> 00:42:46,500
have formed so that's an extended period

910
00:42:50,690 --> 00:42:47,880
and then

911
00:42:54,230 --> 00:42:50,700
in the well

912
00:42:56,990 --> 00:42:54,240
depends how you rate this but not so

913
00:43:01,430 --> 00:42:57,000

long ago in Cosmic history

914
00:43:03,950 --> 00:43:01,440
we now see that it's this expansion

915
00:43:06,710 --> 00:43:03,960
is trying to go towards this uniform

916
00:43:09,410 --> 00:43:06,720
energy density which is the new form of

917
00:43:12,950 --> 00:43:09,420
the Dark Energy so it's a interesting

918
00:43:16,010 --> 00:43:12,960
thing that we begin with what is in

919
00:43:18,349 --> 00:43:16,020
effect Dark Energy Theory which is the

920
00:43:22,069 --> 00:43:18,359
emergence of the universe

921
00:43:25,730 --> 00:43:22,079
and then we end up with a dark energy

922
00:43:27,589 --> 00:43:25,740
which is the late time Behavior so dark

923
00:43:30,770 --> 00:43:27,599
energy dark energy

924
00:43:33,950 --> 00:43:30,780
now what is really curious is that there

925
00:43:37,490 --> 00:43:33,960
is no Grand unified theory between this

926
00:43:39,589 --> 00:43:37,500
and this which is just egregious

927
00:43:41,690 --> 00:43:39,599
but there are many egregious things in

928
00:43:43,569 --> 00:43:41,700
this diagram which I have not gotten

929
00:43:46,790 --> 00:43:43,579
into not egregious

930
00:43:49,190 --> 00:43:46,800
hints that we haven't folded into the

931
00:43:52,130 --> 00:43:49,200
full unfolding of the cosmic Evolution

932
00:43:52,849 --> 00:43:52,140
story for example

933
00:43:55,730 --> 00:43:52,859
um

934
00:43:58,490 --> 00:43:55,740
the passage from when it was dominated

935
00:44:02,030 --> 00:43:58,500
by radiation to when it was dominated by

936
00:44:08,050 --> 00:44:02,040
matter happens to be quite close

937
00:44:11,589 --> 00:44:08,060
relatively close in time to when the uh

938
00:44:14,329 --> 00:44:11,599

electrons started to uh

939
00:44:16,490 --> 00:44:14,339
coalesce onto the protons and make

940
00:44:19,849 --> 00:44:16,500
hydrogen atoms so the universe passed

941
00:44:22,010 --> 00:44:19,859
from uh fully ionized plasma into

942
00:44:24,770 --> 00:44:22,020
largely neutral medium

943
00:44:25,790 --> 00:44:24,780
and that that those numbers are close to

944
00:44:28,609 --> 00:44:25,800
each other

945
00:44:31,550 --> 00:44:28,619
is weird and there's no explanation for

946
00:44:34,370 --> 00:44:31,560
that similarly there's no explanation

947
00:44:35,270 --> 00:44:34,380
although people have tried of course for

948
00:44:40,370 --> 00:44:35,280
why

949
00:44:42,770 --> 00:44:40,380
the amount of baryons ordinary matter is

950
00:44:45,650 --> 00:44:42,780
so closely tied to the amount of dark

951
00:44:47,630 --> 00:44:45,660
matter there's sort of a factor of six

952
00:44:50,770 --> 00:44:47,640
in between them but six in cosmological

953
00:44:53,630 --> 00:44:50,780
terms isn't very much and so

954
00:44:56,870 --> 00:44:53,640
a full Theory should be able to tell us

955
00:44:59,630 --> 00:44:56,880
exactly why that so and it can emerge

956
00:45:01,790 --> 00:44:59,640
it's just that there is no

957
00:45:05,089 --> 00:45:01,800
uh solidified

958
00:45:08,809 --> 00:45:05,099
uh understanding of why that should be

959
00:45:11,870 --> 00:45:08,819
true there I think you want to mention

960
00:45:14,150 --> 00:45:11,880
wimps in the future uh there was

961
00:45:17,210 --> 00:45:14,160
something called the wimp Miracle which

962
00:45:19,930 --> 00:45:17,220
does tend to give

963
00:45:22,910 --> 00:45:19,940

a by chance relationship between the two

964
00:45:26,450 --> 00:45:22,920
but you know just well anyway I can go

965
00:45:29,990 --> 00:45:26,460
on and on so uh maybe

966
00:45:33,349 --> 00:45:30,000
um you might want to redirect me into

967
00:45:36,050 --> 00:45:33,359
something else I have just given you the

968
00:45:37,490 --> 00:45:36,060
full thermal evolutionary history of the

969
00:45:39,770 --> 00:45:37,500
universe and then a question that

970
00:45:40,970 --> 00:45:39,780
naturally comes to mind

971
00:45:43,550 --> 00:45:40,980
again

972
00:45:46,490 --> 00:45:43,560
what happened it's a good prop it's well

973
00:45:48,650 --> 00:45:46,500
arranged uh what happened before here

974
00:45:50,870 --> 00:45:48,660
that's Time Zero

975
00:45:53,270 --> 00:45:50,880
and what's going to happen out here

976
00:45:54,230 --> 00:45:53,280
which is time Infinity if there is such

977
00:45:57,589 --> 00:45:54,240
a thing

978
00:45:59,210 --> 00:45:57,599
and uh obviously uh

979
00:46:01,670 --> 00:45:59,220
you know

980
00:46:03,770 --> 00:46:01,680
we may have a lot of hubris but not that

981
00:46:05,569 --> 00:46:03,780
much hubris but the standard picture is

982
00:46:08,990 --> 00:46:05,579
that if it really is

983
00:46:12,349 --> 00:46:09,000
a potential energy dominated then the

984
00:46:14,329 --> 00:46:12,359
expansion just continues exponentially

985
00:46:16,210 --> 00:46:14,339
that doesn't mean that everything

986
00:46:19,490 --> 00:46:16,220
disappears

987
00:46:22,550 --> 00:46:19,500
that's ordinary it's just that

988
00:46:23,390 --> 00:46:22,560

everything is big

989
00:46:27,109 --> 00:46:23,400
um

990
00:46:29,650 --> 00:46:27,119
uh kind of not fully but somewhat torn

991
00:46:33,950 --> 00:46:29,660
apart by the dark energy

992
00:46:38,630 --> 00:46:33,960
which is trying to do an accelerated

993
00:46:41,150 --> 00:46:38,640
expansion so even things that are stable

994
00:46:42,349 --> 00:46:41,160
right now might not be stable I mean

995
00:46:46,130 --> 00:46:42,359
there are many reasons for the

996
00:46:48,650 --> 00:46:46,140
instability but uh then you know

997
00:46:51,050 --> 00:46:48,660
uh Once Upon a Time fooled around with a

998
00:46:54,650 --> 00:46:51,060
theory in which this would go up like

999
00:46:56,870 --> 00:46:54,660
that where the density goes up that's uh

1000
00:46:58,670 --> 00:46:56,880
and then it would go up to a point and

1001
00:47:03,230 --> 00:46:58,680
start the whole cycle again which is

1002
00:47:05,630 --> 00:47:03,240
Corner kind of a uh a

1003
00:47:07,250 --> 00:47:05,640
a cyclical version of the universe of

1004
00:47:09,230 --> 00:47:07,260
which you know many people have played

1005
00:47:12,470 --> 00:47:09,240
that game over time and it's still

1006
00:47:14,390 --> 00:47:12,480
popular in certain circles but the main

1007
00:47:17,569 --> 00:47:14,400
point is we don't know it's really

1008
00:47:19,730 --> 00:47:17,579
interesting physics if it's true but we

1009
00:47:22,190 --> 00:47:19,740
don't have an indication really about

1010
00:47:25,490 --> 00:47:22,200
you know what the long-term behavior is

1011
00:47:26,270 --> 00:47:25,500
here so we can't really predict our

1012
00:47:31,730 --> 00:47:26,280
future

1013
00:47:33,589 --> 00:47:31,740

and uh what is I I have my own ideas

1014
00:47:37,790 --> 00:47:33,599
not that different from some other

1015
00:47:41,329 --> 00:47:37,800
people's ideas on uh how we go from

1016
00:47:43,849 --> 00:47:41,339
Before Time Zero through two there is no

1017
00:47:48,050 --> 00:47:43,859
time zero is the basic

1018
00:47:51,530 --> 00:47:48,060
uh answer it it is uh

1019
00:47:54,410 --> 00:47:51,540
uh that

1020
00:47:56,569 --> 00:47:54,420
the expansion of the universe which is

1021
00:47:58,970 --> 00:47:56,579
necessary the coherent expansion of the

1022
00:48:02,329 --> 00:47:58,980
universe which is necessary to make the

1023
00:48:03,650 --> 00:48:02,339
universe as we see it around us it

1024
00:48:08,390 --> 00:48:03,660
emerges

1025
00:48:10,609 --> 00:48:08,400
maybe it's you could call it a Quantum

1026
00:48:12,950 --> 00:48:10,619
soup or something with again

1027
00:48:16,430 --> 00:48:12,960
fluctuations all over the place

1028
00:48:18,829 --> 00:48:16,440
uh anyway all of that is of course I

1029
00:48:21,050 --> 00:48:18,839
mean you have to be very careful here

1030
00:48:24,230 --> 00:48:21,060
what do you know what do you think you

1031
00:48:26,210 --> 00:48:24,240
know and what's heavy speculation

1032
00:48:29,750 --> 00:48:26,220
there's a lot of fun and heavy

1033
00:48:33,170 --> 00:48:29,760
speculation and you know you can do some

1034
00:48:38,809 --> 00:48:33,180
theorizing and what we prize most I'm a

1035
00:48:41,630 --> 00:48:38,819
theorist what you we prize most is a

1036
00:48:44,450 --> 00:48:41,640
the detailed mathematical understanding

1037
00:48:45,950 --> 00:48:44,460
of the kind of phenomenon that one's

1038
00:48:49,609 --> 00:48:45,960

trying to

1039
00:48:51,890 --> 00:48:49,619
uh explore explore mentally you know

1040
00:48:54,109 --> 00:48:51,900
exploring it observationally really not

1041
00:48:56,390 --> 00:48:54,119
these Ultra early effects I mean you

1042
00:48:58,849 --> 00:48:56,400
would like to find some signature of

1043
00:49:00,470 --> 00:48:58,859
what happened at time before the Big

1044
00:49:03,230 --> 00:49:00,480
Bang or whatever and people have

1045
00:49:05,750 --> 00:49:03,240
proposed those things too

1046
00:49:08,270 --> 00:49:05,760
um that there may be relics those sort

1047
00:49:12,109 --> 00:49:08,280
of come and go and come and go

1048
00:49:14,270 --> 00:49:12,119
of things that occurred before the

1049
00:49:16,670 --> 00:49:14,280
so-called big bang and propagated

1050
00:49:19,329 --> 00:49:16,680
through it and changed their structural

1051
00:49:21,829 --> 00:49:19,339
forms these are

1052
00:49:23,510 --> 00:49:21,839
highly speculative

1053
00:49:26,089 --> 00:49:23,520
great fun

1054
00:49:28,490 --> 00:49:26,099
and then the question is when you get

1055
00:49:30,950 --> 00:49:28,500
the Avalanche of papers which constantly

1056
00:49:33,410 --> 00:49:30,960
appear on these subjects how much

1057
00:49:36,470 --> 00:49:33,420
attention do you want to give to each

1058
00:49:38,510 --> 00:49:36,480
one because you know a lot of it's

1059
00:49:40,309 --> 00:49:38,520
whistling in the wind as well playing in

1060
00:49:41,390 --> 00:49:40,319
the sandbox is maybe another way to say

1061
00:49:43,250 --> 00:49:41,400
it

1062
00:49:46,329 --> 00:49:43,260
what does the Hubble tension indicate

1063
00:49:51,170 --> 00:49:46,339

about the future of the universe

1064
00:49:52,309 --> 00:49:51,180
this issue of the Hubble tension if it's

1065
00:49:54,170 --> 00:49:52,319
physics

1066
00:49:58,250 --> 00:49:54,180
then it's saying that something

1067
00:50:01,069 --> 00:49:58,260
different than what we think is going on

1068
00:50:03,290 --> 00:50:01,079
uh then there is some kind of Passage

1069
00:50:05,829 --> 00:50:03,300
that has occurred and they

1070
00:50:09,530 --> 00:50:05,839
the time of that Passage would be later

1071
00:50:11,510 --> 00:50:09,540
than when the current Dark Energy

1072
00:50:14,990 --> 00:50:11,520
overtook

1073
00:50:16,569 --> 00:50:15,000
uh the non-relativistic dominance of the

1074
00:50:19,010 --> 00:50:16,579
universe

1075
00:50:20,150 --> 00:50:19,020
and so that's you know obviously

1076
00:50:24,109 --> 00:50:20,160
exciting

1077
00:50:26,870 --> 00:50:24,119
if true and this skepticism or worries

1078
00:50:28,609 --> 00:50:26,880
that occur is that these observational

1079
00:50:32,030 --> 00:50:28,619
campaigns

1080
00:50:34,150 --> 00:50:32,040
are really difficult to get right and

1081
00:50:37,730 --> 00:50:34,160
one of the advantages

1082
00:50:41,750 --> 00:50:37,740
paradoxically of the cosmic microwave

1083
00:50:44,230 --> 00:50:41,760
background at 380 000 years is that it's

1084
00:50:47,410 --> 00:50:44,240
relatively simple to understand

1085
00:50:51,589 --> 00:50:47,420
whereas once you're dealing with real

1086
00:50:54,589 --> 00:50:51,599
astrophysics Supernova and uh cephine

1087
00:50:57,049 --> 00:50:54,599
variable stars and things like this uh

1088
00:50:59,870 --> 00:50:57,059

there are all sorts of effects that you

1089
00:51:03,170 --> 00:50:59,880
may not be able to fully deal with

1090
00:51:05,569 --> 00:51:03,180
theoretically and you just use as

1091
00:51:08,390 --> 00:51:05,579
uh well it looks like this is the trend

1092
00:51:10,549 --> 00:51:08,400
so let's use that law and let's say that

1093
00:51:12,410 --> 00:51:10,559
it's perfect everywhere

1094
00:51:14,450 --> 00:51:12,420
um anyway so that's into the dark energy

1095
00:51:15,170 --> 00:51:14,460
thing so it makes

1096
00:51:17,329 --> 00:51:15,180
um

1097
00:51:21,710 --> 00:51:17,339
I mean nominally

1098
00:51:25,430 --> 00:51:21,720
the density on average is related to

1099
00:51:28,390 --> 00:51:25,440
this Hubble parameter and so if the

1100
00:51:32,870 --> 00:51:28,400
Hubble parameter is like um

1101
00:51:35,930 --> 00:51:32,880
uh 10 difference roughly speaking uh

1102
00:51:38,150 --> 00:51:35,940
according to this Hubble tension then if

1103
00:51:39,710 --> 00:51:38,160
you were really naive you'd say ah

1104
00:51:43,910 --> 00:51:39,720
something has happened

1105
00:51:46,430 --> 00:51:43,920
to cause the H to go up what is that and

1106
00:51:49,130 --> 00:51:46,440
so it wouldn't be a really profound

1107
00:51:52,250 --> 00:51:49,140
uh implication for the Universe At Large

1108
00:51:53,089 --> 00:51:52,260
if it turns out to be true and we will

1109
00:51:55,609 --> 00:51:53,099
get

1110
00:51:56,990 --> 00:51:55,619
the better and better experimental

1111
00:51:58,970 --> 00:51:57,000
information on this I mean there's no

1112
00:52:03,049 --> 00:51:58,980
question we have these huge campaigns

1113
00:52:06,470 --> 00:52:03,059

that are going on uh the uh

1114
00:52:07,730 --> 00:52:06,480
James Webb Telescope of course is the

1115
00:52:09,710 --> 00:52:07,740
thing that is

1116
00:52:13,250 --> 00:52:09,720
most uh

1117
00:52:15,770 --> 00:52:13,260
in the public mind but the number of of

1118
00:52:20,690 --> 00:52:15,780
experiments

1119
00:52:24,230 --> 00:52:20,700
the observations observatories in all

1120
00:52:28,069 --> 00:52:24,240
wave mans that are covering the sky is

1121
00:52:30,770 --> 00:52:28,079
just enormous and it's a tribute to

1122
00:52:33,410 --> 00:52:30,780
humans that they've decided that this is

1123
00:52:36,710 --> 00:52:33,420
one of the places where our resources

1124
00:52:38,270 --> 00:52:36,720
should be put into and you know I

1125
00:52:39,950 --> 00:52:38,280
believe in this strongly I should

1126
00:52:42,530 --> 00:52:39,960
because I'm an astronomer but I believe

1127
00:52:45,710 --> 00:52:42,540
in this strongly because it's going back

1128
00:52:47,809 --> 00:52:45,720
to treating the universe in terms of the

1129
00:52:49,910 --> 00:52:47,819
ideas of the Age of Reason which is

1130
00:52:52,790 --> 00:52:49,920
where we were at at the beginning which

1131
00:52:55,130 --> 00:52:52,800
is reasoned how can we reconcile the

1132
00:52:57,829 --> 00:52:55,140
variance of dark matter

1133
00:53:00,349 --> 00:52:57,839
anyway uh but then you were asking about

1134
00:53:02,569 --> 00:53:00,359
the issues of dark matter

1135
00:53:05,990 --> 00:53:02,579
and uh what is it

1136
00:53:08,270 --> 00:53:06,000
and uh we know of it at the moment only

1137
00:53:09,950 --> 00:53:08,280
through its effect on gravity

1138
00:53:13,490 --> 00:53:09,960

uh

1139
00:53:16,430 --> 00:53:13,500
that doesn't mean that it's

1140
00:53:19,609 --> 00:53:16,440
um not in dark matter or that other

1141
00:53:21,109 --> 00:53:19,619
alternatives are reasonable I mean we

1142
00:53:24,470 --> 00:53:21,119
have a lot of really interesting

1143
00:53:28,549 --> 00:53:24,480
evidence for it that has actually been

1144
00:53:32,390 --> 00:53:28,559
around since the 1930s it sort of picked

1145
00:53:35,089 --> 00:53:32,400
up steam around the early 70s and I'll

1146
00:53:38,990 --> 00:53:35,099
just explain that for a second so in the

1147
00:53:41,829 --> 00:53:39,000
30s a very smart guy said you know if

1148
00:53:46,609 --> 00:53:41,839
there wasn't something else

1149
00:53:48,470 --> 00:53:46,619
the lotion of galaxies in a you know

1150
00:53:52,130 --> 00:53:48,480
this is not too long after Hubble right

1151
00:53:55,849 --> 00:53:52,140
Hubble expansion right it the the

1152
00:53:58,549 --> 00:53:55,859
velocities of the galaxies Within

1153
00:54:00,710 --> 00:53:58,559
clusters of galaxies

1154
00:54:02,809 --> 00:54:00,720
the thing would have fallen apart if

1155
00:54:06,349 --> 00:54:02,819
there wasn't something extra and this

1156
00:54:08,750 --> 00:54:06,359
was the dark matter the first indication

1157
00:54:10,250 --> 00:54:08,760
uh then um

1158
00:54:14,630 --> 00:54:10,260
some

1159
00:54:16,910 --> 00:54:14,640
colleagues a very cleverly said you know

1160
00:54:19,849 --> 00:54:16,920
that a Galaxy

1161
00:54:23,329 --> 00:54:19,859
would be unstable

1162
00:54:25,130 --> 00:54:23,339
if there wasn't some kind of dark matter

1163
00:54:27,230 --> 00:54:25,140

holding it together

1164
00:54:29,569 --> 00:54:27,240
so this was an issue of you know

1165
00:54:31,430 --> 00:54:29,579
galaxies a lot of them were in these

1166
00:54:37,069 --> 00:54:31,440
spiral forms

1167
00:54:41,329 --> 00:54:37,079
and uh those would be unstable and so

1168
00:54:44,630 --> 00:54:41,339
the invention was oh let's put a Halo of

1169
00:54:47,750 --> 00:54:44,640
something around it to stop this thing

1170
00:54:51,109 --> 00:54:47,760
going unstable and then the issue is

1171
00:54:53,270 --> 00:54:51,119
what is it well the original idea is

1172
00:54:55,609 --> 00:54:53,280
Let's Be conventional let's just say

1173
00:54:58,670 --> 00:54:55,619
that there's stars but stars that are a

1174
00:55:00,650 --> 00:54:58,680
bit difficult to see and you know I got

1175
00:55:02,150 --> 00:55:00,660
into that and gain we were especially

1176
00:55:04,190 --> 00:55:02,160
interested in whether there could be a

1177
00:55:06,970 --> 00:55:04,200
lot of black holes doing it it's still

1178
00:55:09,410 --> 00:55:06,980
possible that black holes could be the

1179
00:55:12,530 --> 00:55:09,420
dominant Source but we were especially

1180
00:55:14,390 --> 00:55:12,540
interested in uh black holes that might

1181
00:55:17,030 --> 00:55:14,400
have come from an early generation of

1182
00:55:18,230 --> 00:55:17,040
stars rather than from the ultra of the

1183
00:55:20,990 --> 00:55:18,240
universe if they come from the ultra

1184
00:55:23,710 --> 00:55:21,000
Elite Universe it's like other forms of

1185
00:55:26,150 --> 00:55:23,720
dark matter you might call them wimps

1186
00:55:28,089 --> 00:55:26,160
except that it would be they're called

1187
00:55:33,470 --> 00:55:28,099
primordial black holes

1188
00:55:34,190 --> 00:55:33,480

anyway there's that possibility then

1189
00:55:35,569 --> 00:55:34,200
um

1190
00:55:38,690 --> 00:55:35,579
uh

1191
00:55:42,170 --> 00:55:38,700
there was a period where neutrino well

1192
00:55:44,030 --> 00:55:42,180
neutrinos do have masses but it was

1193
00:55:46,250 --> 00:55:44,040
possible that their masses would be such

1194
00:55:48,290 --> 00:55:46,260
that they could make the dark matter and

1195
00:55:50,390 --> 00:55:48,300
that was extremely exciting but it made

1196
00:55:52,790 --> 00:55:50,400
certain predictions which turned out not

1197
00:55:55,430 --> 00:55:52,800
to be true it's still a component of

1198
00:55:57,950 --> 00:55:55,440
dark matter but not the dominant one and

1199
00:56:00,950 --> 00:55:57,960
then as we explored it further we said

1200
00:56:03,470 --> 00:56:00,960
okay well you know it can't be the

1201
00:56:06,290 --> 00:56:03,480
neutrinos because they were created from

1202
00:56:09,230 --> 00:56:06,300
the early Universe moving too fast

1203
00:56:11,690 --> 00:56:09,240
uh so let's deal with a colder variety

1204
00:56:15,230 --> 00:56:11,700
and that's called cold dark matter

1205
00:56:19,930 --> 00:56:15,240
and uh I had a lot of fun exploring all

1206
00:56:24,589 --> 00:56:19,940
of those possibilities in the uh

1207
00:56:26,870 --> 00:56:24,599
early 80s actually through to now and uh

1208
00:56:29,569 --> 00:56:26,880
you know then an issue is just like with

1209
00:56:32,530 --> 00:56:29,579
the dark energy but even more so

1210
00:56:36,670 --> 00:56:32,540
what are the interactions of this stuff

1211
00:56:42,109 --> 00:56:36,680
and that manifests itself in a few ways

1212
00:56:44,870 --> 00:56:42,119
uh to create it and decouple it

1213
00:56:47,470 --> 00:56:44,880

uh that requires interaction Beyond

1214
00:56:51,530 --> 00:56:47,480
gravity and that would be early universe

1215
00:56:53,510 --> 00:56:51,540
so uh and there are various things that

1216
00:56:55,970 --> 00:56:53,520
can be dark matter that arise in the

1217
00:56:59,870 --> 00:56:55,980
early Universe one of them is these

1218
00:57:02,809 --> 00:56:59,880
weekly interacting massive particles the

1219
00:57:05,210 --> 00:57:02,819
weekly interacting that's what neutrinos

1220
00:57:07,970 --> 00:57:05,220
are they're weakly interacting it's just

1221
00:57:10,490 --> 00:57:07,980
that the mass is a bit higher here than

1222
00:57:13,069 --> 00:57:10,500
the neutrino masses which is why they

1223
00:57:15,470 --> 00:57:13,079
turn out to be cold but then there are

1224
00:57:19,730 --> 00:57:15,480
other possibilities that there is this

1225
00:57:22,190 --> 00:57:19,740
sort of more wave-like dark matter

1226
00:57:27,589 --> 00:57:22,200
um just to give the term they're called

1227
00:57:30,170 --> 00:57:27,599
axialins that also were emerging at the

1228
00:57:32,089 --> 00:57:30,180
time and that we folded into the

1229
00:57:35,089 --> 00:57:32,099
possibilities for the cold Dark Matter

1230
00:57:37,790 --> 00:57:35,099
so those were kind of the panoplay of

1231
00:57:40,390 --> 00:57:37,800
things that were on the table with a lot

1232
00:57:43,910 --> 00:57:40,400
of work on the weekly interacting

1233
00:57:45,650 --> 00:57:43,920
massive particles sort and the different

1234
00:57:50,569 --> 00:57:45,660
theories that could give rise to them

1235
00:57:52,970 --> 00:57:50,579
and then the exciting issue was uh that

1236
00:57:56,030 --> 00:57:52,980
if they have interactions which they

1237
00:57:58,490 --> 00:57:56,040
must have to have decoupled in the early

1238
00:58:00,589 --> 00:57:58,500

Universe it means that those same

1239
00:58:02,329 --> 00:58:00,599
interactions can manifest themselves

1240
00:58:05,450 --> 00:58:02,339
around us

1241
00:58:09,049 --> 00:58:05,460
and so you know huge expenditures have

1242
00:58:11,990 --> 00:58:09,059
occurred to try and directly detect the

1243
00:58:15,170 --> 00:58:12,000
dark matter not just gravitationally but

1244
00:58:17,390 --> 00:58:15,180
in for example uh

1245
00:58:20,030 --> 00:58:17,400
now that we're here in Canada the

1246
00:58:22,190 --> 00:58:20,040
Sudbury neutrino observatory in Sudbury

1247
00:58:24,710 --> 00:58:22,200
which is a very deep mine

1248
00:58:27,770 --> 00:58:24,720
has got a lot of experiments that are

1249
00:58:29,390 --> 00:58:27,780
trying to detect the evidence for the

1250
00:58:32,510 --> 00:58:29,400
dark matter if it's all around us

1251
00:58:37,609 --> 00:58:32,520
coursing through the Earth and making

1252
00:58:40,549 --> 00:58:37,619
reactions that you can then infer the

1253
00:58:43,549 --> 00:58:40,559
nature of dark matter

1254
00:58:45,950 --> 00:58:43,559
the executive summary is that after all

1255
00:58:48,049 --> 00:58:45,960
of this time we still have the situation

1256
00:58:53,510 --> 00:58:48,059
where dark matter

1257
00:58:56,690 --> 00:58:53,520
has an uncertainty in its mass that's uh

1258
00:58:59,809 --> 00:58:56,700
what 60 orders of magnitude at least in

1259
00:59:02,329 --> 00:58:59,819
other words we still don't know

1260
00:59:05,089 --> 00:59:02,339
thought that doesn't mean that dark

1261
00:59:06,609 --> 00:59:05,099
matter is that there it is there it's

1262
00:59:09,650 --> 00:59:06,619
just a question of

1263
00:59:11,510 --> 00:59:09,660

how do we actually detect it by known

1264
00:59:13,069 --> 00:59:11,520
gravitational means

1265
00:59:14,770 --> 00:59:13,079
can you walk us through one of your

1266
00:59:17,930 --> 00:59:14,780
academic Adventures

1267
00:59:19,309 --> 00:59:17,940
it's more of how I approach things which

1268
00:59:22,730 --> 00:59:19,319
is

1269
00:59:26,329 --> 00:59:22,740
um early on I got enamored by

1270
00:59:29,390 --> 00:59:26,339
uh the universe as a collective I mean

1271
00:59:31,609 --> 00:59:29,400
it is but you know that it really got

1272
00:59:32,569 --> 00:59:31,619
into me so that if you have a slab of

1273
00:59:35,750 --> 00:59:32,579
matter

1274
00:59:38,150 --> 00:59:35,760
let's take this table as an example and

1275
00:59:40,609 --> 00:59:38,160
because I uh did a lot of my original

1276
00:59:43,010 --> 00:59:40,619
research at the beginning on neutrinos

1277
00:59:45,349 --> 00:59:43,020
they're really weakly interacting so you

1278
00:59:47,210 --> 00:59:45,359
have neutrinos coming in they do this

1279
00:59:50,630 --> 00:59:47,220
little tickling

1280
00:59:53,030 --> 00:59:50,640
and in order to get the response you

1281
00:59:55,609 --> 00:59:53,040
think of this entire table as a thing

1282
00:59:57,349 --> 00:59:55,619
that's responding even though you know

1283
01:00:00,349 --> 00:59:57,359
we're used to thinking about Point light

1284
01:00:02,750 --> 01:00:00,359
phenomenon but there is a whole

1285
01:00:06,770 --> 01:00:02,760
collectivity of things so that's point

1286
01:00:08,809 --> 01:00:06,780
one I love the collective and how and

1287
01:00:10,309 --> 01:00:08,819
that's the whole idea of the cosmic web

1288
01:00:12,829 --> 01:00:10,319

everything interconnected with

1289
01:00:15,890 --> 01:00:12,839
everything else but then the other great

1290
01:00:18,710 --> 01:00:15,900
passion I have is for entropy

1291
01:00:22,789 --> 01:00:18,720
and entropy of course it was a

1292
01:00:25,490 --> 01:00:22,799
thermodynamic concept uh that was

1293
01:00:28,670 --> 01:00:25,500
developed to understand heat engines and

1294
01:00:30,589 --> 01:00:28,680
all of that and uh people have been

1295
01:00:32,329 --> 01:00:30,599
struggling with entropy

1296
01:00:35,510 --> 01:00:32,339
uh

1297
01:00:37,849 --> 01:00:35,520
for a very long time and there was this

1298
01:00:41,329 --> 01:00:37,859
guy you may have heard of him Shannon

1299
01:00:42,490 --> 01:00:41,339
who uh was interested in

1300
01:00:45,109 --> 01:00:42,500
information

1301
01:00:48,349 --> 01:00:45,119
flowing along channels

1302
01:00:50,210 --> 01:00:48,359
and um I'm gonna tell the story and

1303
01:00:53,030 --> 01:00:50,220
you're gonna say oh you can do one but

1304
01:00:56,530 --> 01:00:53,040
anyway it was a great story uh Von

1305
01:01:00,349 --> 01:00:56,540
Neumann who is the person that took

1306
01:01:03,109 --> 01:01:00,359
entropy and made it into something that

1307
01:01:06,950 --> 01:01:03,119
was quantum mechanically compatible

1308
01:01:10,490 --> 01:01:06,960
uh Shannon asked of I have this thing

1309
01:01:12,349 --> 01:01:10,500
it's sort of like entropy uh what should

1310
01:01:14,390 --> 01:01:12,359
I call it I said

1311
01:01:17,569 --> 01:01:14,400
just call it anthropy nobody understands

1312
01:01:19,490 --> 01:01:17,579
entropy so my whole career has been

1313
01:01:22,849 --> 01:01:19,500

trying to understand entropy which I now

1314
01:01:24,710 --> 01:01:22,859
think I sort of do in a way I'm still

1315
01:01:27,349 --> 01:01:24,720
struggling with the full Grand unified

1316
01:01:29,809 --> 01:01:27,359
vision of how it relates to everything

1317
01:01:32,589 --> 01:01:29,819
now why is this getting back into your

1318
01:01:37,270 --> 01:01:32,599
other question so I can also of course

1319
01:01:40,370 --> 01:01:37,280
uh expound upon you know specific

1320
01:01:42,829 --> 01:01:40,380
concrete things like you know the role

1321
01:01:45,230 --> 01:01:42,839
in The Cosmic microwave background in

1322
01:01:47,150 --> 01:01:45,240
the cosmic web the things that are you

1323
01:01:49,910 --> 01:01:47,160
know concrete aspects that we've got

1324
01:01:53,690 --> 01:01:49,920
information on but let's go back to this

1325
01:01:55,549 --> 01:01:53,700
more General picture which is more along

1326
01:01:58,430 --> 01:01:55,559
the theme that you're trying to get to

1327
01:02:00,470 --> 01:01:58,440
which is Theory of Everything

1328
01:02:02,150 --> 01:02:00,480
Theory of Everything been around for

1329
01:02:04,730 --> 01:02:02,160
quite a while of course Grand unified

1330
01:02:05,569 --> 01:02:04,740
theory is what everybody's been striving

1331
01:02:07,670 --> 01:02:05,579
for

1332
01:02:10,609 --> 01:02:07,680
so I was at a conference many people

1333
01:02:13,010 --> 01:02:10,619
including Jim Peebles Nobel Prize winner

1334
01:02:15,049 --> 01:02:13,020
we're at a conference on Vancouver

1335
01:02:16,069 --> 01:02:15,059
Island and

1336
01:02:20,450 --> 01:02:16,079
um

1337
01:02:23,770 --> 01:02:20,460
uh playing Tarzan I swung into

1338
01:02:25,930 --> 01:02:23,780

sound crazy but I I swung into a pond

1339
01:02:31,730 --> 01:02:25,940
hit my

1340
01:02:34,190 --> 01:02:31,740
toe on a rock and it broke and so I had

1341
01:02:36,710 --> 01:02:34,200
you know had to do some pain pills or

1342
01:02:39,890 --> 01:02:36,720
something but I had to still do my talks

1343
01:02:43,190 --> 01:02:39,900
so I decided to make this into a cosmic

1344
01:02:45,650 --> 01:02:43,200
joke and said I am now going to tell you

1345
01:02:49,010 --> 01:02:45,660
about my theory of everything

1346
01:02:52,910 --> 01:02:49,020
the toe because that's what it was t-o-e

1347
01:02:55,609 --> 01:02:52,920
the toe right and so I used the whole

1348
01:02:59,990 --> 01:02:55,619
Spiel to make a theory of the universe

1349
01:03:02,809 --> 01:03:00,000
associated with my toe being broken and

1350
01:03:06,049 --> 01:03:02,819
uh the search for solution and healing

1351
01:03:08,510 --> 01:03:06,059
of the toe anyway what is this to get

1352
01:03:11,270 --> 01:03:08,520
across is to get across that if you

1353
01:03:14,390 --> 01:03:11,280
don't have humor in dealing with the

1354
01:03:17,210 --> 01:03:14,400
Quest for toe then your

1355
01:03:20,150 --> 01:03:17,220
not thinking about it right

1356
01:03:22,010 --> 01:03:20,160
people are very serious about their

1357
01:03:24,230 --> 01:03:22,020
search for the grand unified theory

1358
01:03:25,849 --> 01:03:24,240
likely situation as humans will never

1359
01:03:28,789 --> 01:03:25,859
get there but you know you got to keep

1360
01:03:30,230 --> 01:03:28,799
trying what role do higher dimensional

1361
01:03:32,809 --> 01:03:30,240
manifolds play in structuring the

1362
01:03:35,390 --> 01:03:32,819
universe the more important thing than

1363
01:03:38,150 --> 01:03:35,400

metric is the square root of metric

1364
01:03:41,870 --> 01:03:38,160
if you know what I mean it is called uh

1365
01:03:45,470 --> 01:03:41,880
in four dimensions called a fear mine it

1366
01:03:48,349 --> 01:03:45,480
is a field it's a field with labels

1367
01:03:50,089 --> 01:03:48,359
and the labels are

1368
01:03:53,510 --> 01:03:50,099
energy

1369
01:03:56,089 --> 01:03:53,520
so it's like a gauge field

1370
01:03:58,910 --> 01:03:56,099
and one of the parts of it is energy

1371
01:04:02,329 --> 01:03:58,920
energy is in that case like a charge so

1372
01:04:04,910 --> 01:04:02,339
it then means that that quantity

1373
01:04:09,950 --> 01:04:04,920
the fear by and for energy

1374
01:04:12,410 --> 01:04:09,960
is quite quite analogous to

1375
01:04:14,270 --> 01:04:12,420
the photon field the electromagnetic

1376
01:04:16,970 --> 01:04:14,280
field for charge

1377
01:04:18,849 --> 01:04:16,980
they're the same in structure in how

1378
01:04:20,510 --> 01:04:18,859
they play out

1379
01:04:23,329 --> 01:04:20,520
momentum

1380
01:04:25,309 --> 01:04:23,339
with the three dimensions that we now

1381
01:04:27,309 --> 01:04:25,319
have

1382
01:04:29,809 --> 01:04:27,319
of space

1383
01:04:32,030 --> 01:04:29,819
they each have their

1384
01:04:35,809 --> 01:04:32,040
gauge field

1385
01:04:39,170 --> 01:04:35,819
they had their minds and they've couple

1386
01:04:42,829 --> 01:04:39,180
in exactly the same way as the photons

1387
01:04:46,130 --> 01:04:42,839
even more so their coupling it is more

1388
01:04:48,410 --> 01:04:46,140

closely related to how the gluons that

1389
01:04:51,170 --> 01:04:48,420
hold things together work

1390
01:04:52,370 --> 01:04:51,180
so when people ask and that was one of

1391
01:04:56,150 --> 01:04:52,380
the questions which I think you were

1392
01:04:59,089 --> 01:04:56,160
trying to get at is is gravity real

1393
01:05:02,870 --> 01:04:59,099
and I will tell you that if

1394
01:05:04,970 --> 01:05:02,880
gravity is very very similar to all of

1395
01:05:08,510 --> 01:05:04,980
these other situations

1396
01:05:11,329 --> 01:05:08,520
the interesting thing is that you put

1397
01:05:12,589 --> 01:05:11,339
energy together

1398
01:05:15,170 --> 01:05:12,599
with

1399
01:05:16,970 --> 01:05:15,180
uh this

1400
01:05:20,150 --> 01:05:16,980
fear mind

1401
01:05:21,349 --> 01:05:20,160
they've coupled together tightly and

1402
01:05:23,270 --> 01:05:21,359
that makes

1403
01:05:28,130 --> 01:05:23,280
action

1404
01:05:29,750 --> 01:05:28,140
particle physics paper the very first

1405
01:05:33,530 --> 01:05:29,760
thing they do is they write down the

1406
01:05:36,349 --> 01:05:33,540
action the action is the thing that is

1407
01:05:38,450 --> 01:05:36,359
coupling the forces of action and

1408
01:05:41,690 --> 01:05:38,460
reaction together

1409
01:05:44,450 --> 01:05:41,700
and it causes the whole process to occur

1410
01:05:46,670 --> 01:05:44,460
not unlike yin and yang actually but you

1411
01:05:49,789 --> 01:05:46,680
know one could riff off of these

1412
01:05:52,549 --> 01:05:49,799
philosophical thoughts but basically the

1413
01:05:58,069 --> 01:05:52,559

structure of

1414
01:06:00,710 --> 01:05:58,079
of the universe seems to be that uh you

1415
01:06:03,890 --> 01:06:00,720
have something akin to a charge and then

1416
01:06:07,490 --> 01:06:03,900
the universe or the Reservoir or

1417
01:06:09,950 --> 01:06:07,500
whatever or the vacuum is responding to

1418
01:06:12,230 --> 01:06:09,960
the charge and the two are tightly

1419
01:06:13,970 --> 01:06:12,240
coupled together an interesting question

1420
01:06:16,430 --> 01:06:13,980
from my perspective now is how tightly

1421
01:06:20,089 --> 01:06:16,440
they're coupled together but the main

1422
01:06:24,170 --> 01:06:20,099
point is that they form this quantity

1423
01:06:28,670 --> 01:06:24,180
together so this concept of gravity

1424
01:06:32,049 --> 01:06:28,680
being so different is in my view just

1425
01:06:35,270 --> 01:06:32,059
people play it in the sandbox but

1426
01:06:38,210 --> 01:06:35,280
it's uh dirty sand or something is

1427
01:06:40,010 --> 01:06:38,220
gravity an emergent property people have

1428
01:06:42,109 --> 01:06:40,020
played with

1429
01:06:44,510 --> 01:06:42,119
um an attempt to make what is in effect

1430
01:06:46,490 --> 01:06:44,520
a thermodynamic view where the

1431
01:06:49,069 --> 01:06:46,500
thermodynamic or non-thermodynamics same

1432
01:06:51,109 --> 01:06:49,079
thing it's just that um

1433
01:06:54,349 --> 01:06:51,119
I mean again it's kind of playing with

1434
01:06:58,390 --> 01:06:54,359
ideas but in my view not looking at them

1435
01:07:04,910 --> 01:07:01,730
thermodynamics is

1436
01:07:05,770 --> 01:07:04,920
not just you know temperature or

1437
01:07:09,170 --> 01:07:05,780
something

1438
01:07:12,589 --> 01:07:09,180

fundamental is change

1439
01:07:14,569 --> 01:07:12,599
and so in any thermodynamic system of

1440
01:07:17,450 --> 01:07:14,579
which this room is an example it's an

1441
01:07:21,710 --> 01:07:17,460
open one but it's true uh there are

1442
01:07:25,789 --> 01:07:21,720
thermodynamic fluctuations all over and

1443
01:07:29,390 --> 01:07:25,799
there are gradients in the thermodynamic

1444
01:07:32,150 --> 01:07:29,400
uh potentials that cause things to move

1445
01:07:34,370 --> 01:07:32,160
for example from hot to cold I mean

1446
01:07:37,190 --> 01:07:34,380
that's you know standard thing

1447
01:07:39,770 --> 01:07:37,200
that actually is the story of entropy

1448
01:07:43,250 --> 01:07:39,780
which is internally related to the story

1449
01:07:46,309 --> 01:07:43,260
of action which is also gradients

1450
01:07:47,450 --> 01:07:46,319
associated with flowing from here to

1451
01:07:49,130 --> 01:07:47,460
there

1452
01:07:52,789 --> 01:07:49,140
so

1453
01:07:54,049 --> 01:07:52,799
the second derivative of these things

1454
01:07:56,870 --> 01:07:54,059
is

1455
01:07:58,910 --> 01:07:56,880
got all of the aspects or many of the

1456
01:08:01,309 --> 01:07:58,920
aspects of curvature associated with it

1457
01:08:04,490 --> 01:08:01,319
and curvature is one way that we

1458
01:08:07,130 --> 01:08:04,500
understand how gravity is operating and

1459
01:08:09,710 --> 01:08:07,140
so uh

1460
01:08:13,549 --> 01:08:09,720
what we're dealing with is an attempt to

1461
01:08:16,669 --> 01:08:13,559
find a language but the thing is all the

1462
01:08:19,430 --> 01:08:16,679
languages are all ultimately going to

1463
01:08:21,110 --> 01:08:19,440

tell us the same thing it's just that if

1464
01:08:23,450 --> 01:08:21,120
you hear something in different

1465
01:08:25,729 --> 01:08:23,460
languages or different words you can get

1466
01:08:28,669 --> 01:08:25,739
further insight and then some people get

1467
01:08:30,890 --> 01:08:28,679
locked into just a single language it is

1468
01:08:33,890 --> 01:08:30,900
great to develop

1469
01:08:36,169 --> 01:08:33,900
uh a

1470
01:08:40,550 --> 01:08:36,179
many ways of looking at the same

1471
01:08:42,950 --> 01:08:40,560
phenomenon and uh and that can allow you

1472
01:08:45,289 --> 01:08:42,960
to grow so when people want to sit oh

1473
01:08:46,669 --> 01:08:45,299
it's just thermodynamics

1474
01:08:48,110 --> 01:08:46,679
I don't think they're thinking about it

1475
01:08:50,689 --> 01:08:48,120
deeply enough

1476
01:08:52,849 --> 01:08:50,699
uh but if they're saying it's just

1477
01:08:55,669 --> 01:08:52,859
classical curvature

1478
01:08:57,829 --> 01:08:55,679
and that gravity is really classical

1479
01:09:01,309 --> 01:08:57,839
they're not thinking about it enough

1480
01:09:04,430 --> 01:09:01,319
uh so to me

1481
01:09:08,329 --> 01:09:04,440
that is not the mystery

1482
01:09:11,809 --> 01:09:08,339
and the structure is not the mystery the

1483
01:09:13,990 --> 01:09:11,819
mystery is perhaps and don't get right

1484
01:09:15,950 --> 01:09:14,000
back to it

1485
01:09:18,289 --> 01:09:15,960
is uh

1486
01:09:20,689 --> 01:09:18,299
how things emerged

1487
01:09:23,090 --> 01:09:20,699
and what did they emerge from

1488
01:09:25,910 --> 01:09:23,100

I think you know I can play around with

1489
01:09:29,450 --> 01:09:25,920
ideas of what was there

1490
01:09:32,510 --> 01:09:29,460
that cause Divergence my view is that

1491
01:09:34,610 --> 01:09:32,520
apart from entropy and phase which is

1492
01:09:35,289 --> 01:09:34,620
also called quantum mechanics it turns

1493
01:09:38,329 --> 01:09:35,299
out

1494
01:09:41,990 --> 01:09:38,339
the log of

1495
01:09:43,550 --> 01:09:42,000
uh Schrodinger's Psy

1496
01:09:45,769 --> 01:09:43,560
wave function

1497
01:09:47,090 --> 01:09:45,779
is

1498
01:09:49,070 --> 01:09:47,100
I

1499
01:09:53,390 --> 01:09:49,080
times

1500
01:09:55,250 --> 01:09:53,400
complex action of which the real part is

1501
01:09:58,189 --> 01:09:55,260
the usual action

1502
01:10:01,490 --> 01:09:58,199
and the imaginary part is one half of

1503
01:10:05,030 --> 01:10:01,500
the um entropy

1504
01:10:08,150 --> 01:10:05,040
that's the universal relationship and at

1505
01:10:11,750 --> 01:10:08,160
its heart is the Quantum phenomenon

1506
01:10:13,550 --> 01:10:11,760
and quantum mechanics is

1507
01:10:17,330 --> 01:10:13,560
the language of the universe and what

1508
01:10:20,750 --> 01:10:17,340
it's doing it's saying that I do not

1509
01:10:23,630 --> 01:10:20,760
I there are forces that are there in

1510
01:10:26,870 --> 01:10:23,640
Schrodinger's equation for example that

1511
01:10:30,110 --> 01:10:26,880
try and take the Ensemble of possible

1512
01:10:32,930 --> 01:10:30,120
realizations and make sure that they're

1513
01:10:36,189 --> 01:10:32,940

spread apart see now I'm getting into

1514
01:10:42,590 --> 01:10:39,410
obviously some uncertainty but that is

1515
01:10:43,850 --> 01:10:42,600
where we are headed in my view I mean I

1516
01:10:47,149 --> 01:10:43,860
am headed there

1517
01:10:50,149 --> 01:10:47,159
and what I am seeing is that everybody's

1518
01:10:52,250 --> 01:10:50,159
headed there that is to say the concept

1519
01:10:54,830 --> 01:10:52,260
of information and the laws of

1520
01:10:58,189 --> 01:10:54,840
information which is quantum information

1521
01:11:00,410 --> 01:10:58,199
all quantum is the underlying

1522
01:11:03,669 --> 01:11:00,420
architecture of everything

1523
01:11:07,370 --> 01:11:03,679
and so when you say is gravity

1524
01:11:09,770 --> 01:11:07,380
quantum mechanics writ large yes it is

1525
01:11:12,410 --> 01:11:09,780
but that's because it splits into

1526
01:11:15,110 --> 01:11:12,420
entropy in action and the way entropy

1527
01:11:19,550 --> 01:11:15,120
and action work is that it's a product

1528
01:11:22,790 --> 01:11:19,560
of charge times response to charge so

1529
01:11:24,229 --> 01:11:22,800
that this is kind of the universal story

1530
01:11:26,330 --> 01:11:24,239
so then

1531
01:11:28,790 --> 01:11:26,340
getting back to your questions I haven't

1532
01:11:31,250 --> 01:11:28,800
forgotten it which is something about

1533
01:11:34,850 --> 01:11:31,260
spin spin's really interesting here and

1534
01:11:38,330 --> 01:11:34,860
we could Riff on that for a while but uh

1535
01:11:42,970 --> 01:11:38,340
the basic point is that the metric

1536
01:11:46,970 --> 01:11:42,980
picture is a picture of uh

1537
01:11:51,530 --> 01:11:46,980
effectively even though it's done as a

1538
01:11:55,610 --> 01:11:51,540

metric squared about distance squared at

1539
01:11:58,610 --> 01:11:55,620
some level it is an expression of

1540
01:12:01,790 --> 01:11:58,620
either action squared or entropy squared

1541
01:12:04,130 --> 01:12:01,800
and so okay that's interesting

1542
01:12:06,169 --> 01:12:04,140
uh but

1543
01:12:07,910 --> 01:12:06,179
it's like

1544
01:12:09,709 --> 01:12:07,920
ah what am I going to say there's

1545
01:12:11,630 --> 01:12:09,719
something called the density Matrix and

1546
01:12:14,510 --> 01:12:11,640
quantum mechanics which encodes all of

1547
01:12:18,229 --> 01:12:14,520
the information and it basically is

1548
01:12:21,649 --> 01:12:18,239
telling you about how a system changes

1549
01:12:24,890 --> 01:12:21,659
from one form to another

1550
01:12:27,110 --> 01:12:24,900
um and what we do is we split it up into

1551
01:12:31,250 --> 01:12:27,120
a product and we call that product the

1552
01:12:34,310 --> 01:12:31,260
wave function so the density is a

1553
01:12:36,590 --> 01:12:34,320
quadratic combination of wave functions

1554
01:12:39,229 --> 01:12:36,600
and what's interesting about that is

1555
01:12:42,229 --> 01:12:39,239
that it's a complex product so there are

1556
01:12:43,669 --> 01:12:42,239
two elements one is action which is

1557
01:12:46,910 --> 01:12:43,679
phase

1558
01:12:50,030 --> 01:12:46,920
and then uh and then there's the overall

1559
01:12:51,229 --> 01:12:50,040
density aspect which is entropy entropy

1560
01:12:55,070 --> 01:12:51,239
is count

1561
01:12:57,649 --> 01:12:55,080
and a phase is coherence among counts so

1562
01:13:00,830 --> 01:12:57,659
I've taken you to where I am actually

1563
01:13:02,030 --> 01:13:00,840

spending much of my thinking and how am

1564
01:13:05,149 --> 01:13:02,040
I doing it

1565
01:13:08,810 --> 01:13:05,159
I'm doing it by concrete problems with

1566
01:13:11,570 --> 01:13:08,820
many of my colleagues around here so the

1567
01:13:13,550 --> 01:13:11,580
theory of inflation is a fantastic

1568
01:13:15,649 --> 01:13:13,560
playground for all of these ideas

1569
01:13:19,010 --> 01:13:15,659
because

1570
01:13:20,270 --> 01:13:19,020
I want to use you know something which

1571
01:13:23,570 --> 01:13:20,280
can actually have observable

1572
01:13:24,890 --> 01:13:23,580
consequences in order to improve my

1573
01:13:27,169 --> 01:13:24,900
comprehension of how the universe

1574
01:13:31,010 --> 01:13:27,179
actually works so that's what the quest

1575
01:13:32,870 --> 01:13:31,020
is now if you were talking about spin

1576
01:13:35,870 --> 01:13:32,880
metrics well the first point is that

1577
01:13:37,790 --> 01:13:35,880
usually we deal with four dimensions

1578
01:13:41,390 --> 01:13:37,800
time three space

1579
01:13:44,090 --> 01:13:41,400
then within String Theory there was an

1580
01:13:45,590 --> 01:13:44,100
argument for it being depending upon how

1581
01:13:46,910 --> 01:13:45,600
you did it 10 Dimensions or 11

1582
01:13:48,830 --> 01:13:46,920
dimensions

1583
01:13:52,970 --> 01:13:48,840
to me

1584
01:13:58,010 --> 01:13:52,980
every degree of freedom is a dimension

1585
01:13:59,770 --> 01:13:58,020
which means that it's x y z t

1586
01:14:03,169 --> 01:13:59,780
Z by the way

1587
01:14:04,910 --> 01:14:03,179
and then all the fields

1588
01:14:08,209 --> 01:14:04,920

and the fields

1589
01:14:12,290 --> 01:14:08,219
are dimensions why not

1590
01:14:14,630 --> 01:14:12,300
and so then the issue is is a particle a

1591
01:14:17,810 --> 01:14:14,640
particle itself a field or is it always

1592
01:14:23,510 --> 01:14:17,820
a collection and that's an interesting

1593
01:14:26,510 --> 01:14:23,520
uh issue so in my view dimensions are

1594
01:14:28,850 --> 01:14:26,520
relatively easy to create and Destroy

1595
01:14:31,430 --> 01:14:28,860
and it is not something that people

1596
01:14:33,470 --> 01:14:31,440
should be overly intimidated by but of

1597
01:14:35,990 --> 01:14:33,480
course historically we had this path

1598
01:14:37,910 --> 01:14:36,000
which meant that people's minds were

1599
01:14:40,850 --> 01:14:37,920
kind of uh

1600
01:14:42,410 --> 01:14:40,860
Frozen in because it takes time for

1601
01:14:44,990 --> 01:14:42,420
people to adapt

1602
01:14:48,370 --> 01:14:45,000
and now I'd say that

1603
01:14:51,050 --> 01:14:48,380
partly because String Theory didn't

1604
01:14:53,330 --> 01:14:51,060
break make the breakthroughs that people

1605
01:14:57,470 --> 01:14:53,340
had thought because it's complicated I

1606
01:14:58,850 --> 01:14:57,480
mean it may still be underlying but as a

1607
01:15:02,209 --> 01:14:58,860
result of that

1608
01:15:03,410 --> 01:15:02,219
all these bright Minds have been pushing

1609
01:15:06,530 --> 01:15:03,420
at

1610
01:15:09,950 --> 01:15:06,540
all these other questions in physics and

1611
01:15:12,649 --> 01:15:09,960
it seems to me we're on the cusp of a

1612
01:15:14,090 --> 01:15:12,659
real breakthrough in what unifies the

1613
01:15:16,850 --> 01:15:14,100

whole thing together

1614
01:15:18,950 --> 01:15:16,860
is essentially information Theory I mean

1615
01:15:21,050 --> 01:15:18,960
and I'm not the only one saying this

1616
01:15:22,669 --> 01:15:21,060
it's just that I came to it from a very

1617
01:15:24,110 --> 01:15:22,679
different route it's basically been

1618
01:15:25,970 --> 01:15:24,120
where I've been going all along but now

1619
01:15:29,750 --> 01:15:25,980
I see he's doing he's doing she's doing

1620
01:15:32,570 --> 01:15:29,760
it she's doing it that is what is kind

1621
01:15:34,850 --> 01:15:32,580
of dominating the lines and then what it

1622
01:15:37,250 --> 01:15:34,860
blends with is the Google lights in this

1623
01:15:38,510 --> 01:15:37,260
world because they see the world as

1624
01:15:54,050 --> 01:15:38,520
information

1625
01:15:56,510 --> 01:15:54,060
same thing

1626
01:15:59,209 --> 01:15:56,520
so if we are talking about a Theory of

1627
01:16:05,330 --> 01:15:59,219
Everything a grand unified theory

1628
01:16:08,209 --> 01:16:05,340
then it must fundamentally engage in

1629
01:16:10,729 --> 01:16:08,219
not just the existence of humans that

1630
01:16:13,850 --> 01:16:10,739
happened on this little planet and you

1631
01:16:16,550 --> 01:16:13,860
know chemical operations of unbelievable

1632
01:16:19,850 --> 01:16:16,560
complexity all came together to produce

1633
01:16:20,689 --> 01:16:19,860
this tremendous force of Life which just

1634
01:16:23,870 --> 01:16:20,699
is

1635
01:16:26,630 --> 01:16:23,880
uh doesn't seem to be well humans look

1636
01:16:30,229 --> 01:16:26,640
like they can repress it but uh is

1637
01:16:32,630 --> 01:16:30,239
irrepressible life everywhere right it's

1638
01:16:35,510 --> 01:16:32,640

something I mean it's amazing

1639
01:16:37,010 --> 01:16:35,520
how if something goes wrong Mother

1640
01:16:39,050 --> 01:16:37,020
Nature comes up with something else

1641
01:16:40,850 --> 01:16:39,060
something else something else that all

1642
01:16:44,149 --> 01:16:40,860
has to be fully integrated and the

1643
01:16:47,090 --> 01:16:44,159
problem is that it seems so impossible

1644
01:16:50,209 --> 01:16:47,100
because everything is so complex

1645
01:16:54,590 --> 01:16:50,219
that how can you make a grand new fight

1646
01:16:57,050 --> 01:16:54,600
Theory well you do it by saying there's

1647
01:17:00,169 --> 01:16:57,060
principles

1648
01:17:02,330 --> 01:17:00,179
you wanted it to be framed in terms of

1649
01:17:03,830 --> 01:17:02,340
laws

1650
01:17:05,390 --> 01:17:03,840
law

1651
01:17:07,790 --> 01:17:05,400
earned clear

1652
01:17:10,310 --> 01:17:07,800
uh I mean that's the way people used to

1653
01:17:13,970 --> 01:17:10,320
think about it right that has Law there

1654
01:17:18,350 --> 01:17:13,980
has been uh from above a law has been

1655
01:17:20,209 --> 01:17:18,360
dictated but laws are created

1656
01:17:24,110 --> 01:17:20,219
just like

1657
01:17:28,010 --> 01:17:24,120
things evolve a law can evolve

1658
01:17:31,010 --> 01:17:28,020
a law is an expression of a collective

1659
01:17:33,490 --> 01:17:31,020
back to Collective and so this is one of

1660
01:17:36,410 --> 01:17:33,500
the interesting things that I'm into now

1661
01:17:37,850 --> 01:17:36,420
we call these things effective

1662
01:17:39,830 --> 01:17:37,860
potentials

1663
01:17:43,550 --> 01:17:39,840

that uh

1664
01:17:44,930 --> 01:17:43,560
Define how flows trajectories realities

1665
01:17:47,810 --> 01:17:44,940
change

1666
01:17:50,209 --> 01:17:47,820
and usually what you do in physics is

1667
01:17:52,550 --> 01:17:50,219
you say Let There be this

1668
01:17:54,970 --> 01:17:52,560
effective potential

1669
01:17:58,250 --> 01:17:54,980
and then let's look at the consequences

1670
01:18:02,030 --> 01:17:58,260
but the view I have is that yeah but it

1671
01:18:05,450 --> 01:18:02,040
feed feeds back in the law or the effect

1672
01:18:07,189 --> 01:18:05,460
and potential changes and so there is a

1673
01:18:10,370 --> 01:18:07,199
feedback then the question is how does

1674
01:18:12,229 --> 01:18:10,380
it all fit together in some to eat but

1675
01:18:16,430 --> 01:18:12,239
the most important thing maybe it's

1676
01:18:18,950 --> 01:18:16,440
because I'm in my dotage is that

1677
01:18:20,750 --> 01:18:18,960
uh but I mean this has always been the

1678
01:18:23,930 --> 01:18:20,760
goal I think it's everybody's goal you

1679
01:18:27,250 --> 01:18:23,940
want to have a grand unified theory that

1680
01:18:30,530 --> 01:18:27,260
includes all of human phenomenology

1681
01:18:34,370 --> 01:18:30,540
and not just from the point of view of

1682
01:18:37,130 --> 01:18:34,380
Us's kind of mechanical beings but us as

1683
01:18:39,830 --> 01:18:37,140
I generators of ideas

1684
01:18:43,850 --> 01:18:39,840
and does this include consciousness

1685
01:18:46,370 --> 01:18:43,860
yeah yeah uh well Consciousness writ

1686
01:18:49,729 --> 01:18:46,380
large that is to say

1687
01:18:53,090 --> 01:18:51,530
you know Plato

1688
01:18:57,070 --> 01:18:53,100

cave

1689
01:19:00,830 --> 01:18:57,080
little ideas become Capital ideas

1690
01:19:04,070 --> 01:19:00,840
capital I and he would have said it's

1691
01:19:07,550 --> 01:19:04,080
the capital ideas which are the real

1692
01:19:11,450 --> 01:19:07,560
truth and the little ideas are just the

1693
01:19:13,790 --> 01:19:11,460
Shadows that are playing out and I'm not

1694
01:19:16,070 --> 01:19:13,800
going to go that far but the profundity

1695
01:19:18,110 --> 01:19:16,080
of their thinking was enormous in my

1696
01:19:20,990 --> 01:19:18,120
view everybody else would say the same

1697
01:19:22,850 --> 01:19:21,000
thing but it isn't translated into this

1698
01:19:27,169 --> 01:19:22,860
world as much as it shouldn't be that

1699
01:19:29,510 --> 01:19:27,179
ideas are the things that have been the

1700
01:19:31,970 --> 01:19:29,520
great creation I mean mother nature

1701
01:19:33,229 --> 01:19:31,980
obviously created though it in some

1702
01:19:34,970 --> 01:19:33,239
sense but

1703
01:19:37,270 --> 01:19:34,980
we have

1704
01:19:40,010 --> 01:19:37,280
something that happened on this planet

1705
01:19:43,610 --> 01:19:40,020
which is the creation of these Mega

1706
01:19:45,229 --> 01:19:43,620
ideas which required many things we had

1707
01:19:48,530 --> 01:19:45,239
to learn writing we had to learn to

1708
01:19:51,290 --> 01:19:48,540
speak to each other we had to that is

1709
01:19:53,570 --> 01:19:51,300
all physics so when you ask what is

1710
01:19:56,990 --> 01:19:53,580
Universe the universe is you and you and

1711
01:19:59,030 --> 01:19:57,000
you and that is the subject that's the

1712
01:20:02,030 --> 01:19:59,040
subject of physics theoretical physics

1713
01:20:03,410 --> 01:20:02,040

it's why I got so impassioned by it from

1714
01:20:05,570 --> 01:20:03,420
the beginning

1715
01:20:07,310 --> 01:20:05,580
because I think I had a glimpse of

1716
01:20:09,890 --> 01:20:07,320
that's what it shouldn't be and could

1717
01:20:11,450 --> 01:20:09,900
become whether or not I'll get there I

1718
01:20:14,870 --> 01:20:11,460
don't know or whether you know I'll go

1719
01:20:17,990 --> 01:20:14,880
blabbering off on this except that it is

1720
01:20:20,930 --> 01:20:18,000
an attempt within you know one being

1721
01:20:22,790 --> 01:20:20,940
to have a mini Grand unification I think

1722
01:20:25,130 --> 01:20:22,800
that's what everybody is trying to do

1723
01:20:27,229 --> 01:20:25,140
they're trying to unify their being

1724
01:20:30,470 --> 01:20:27,239
under

1725
01:20:32,930 --> 01:20:30,480
maybe not just one Capital idea of the

1726
01:20:35,090 --> 01:20:32,940
religion is one Capital idea the

1727
01:20:37,490 --> 01:20:35,100
spirituality play into your life

1728
01:20:40,130 --> 01:20:37,500
I believe in everything and nothing that

1729
01:20:42,649 --> 01:20:40,140
is my Mantra and that is actually a

1730
01:20:43,910 --> 01:20:42,659
fundamental statement of the Universe

1731
01:20:46,850 --> 01:20:43,920
um

1732
01:20:48,770 --> 01:20:46,860
in condensed matter physics what is

1733
01:20:50,689 --> 01:20:48,780
fundamental are things called particles

1734
01:20:54,530 --> 01:20:50,699
and holes

1735
01:20:56,990 --> 01:20:54,540
you know in going back to matter and

1736
01:21:00,110 --> 01:20:57,000
antimatter which you wanted to raise

1737
01:21:01,669 --> 01:21:00,120
earlier of why baryons and not

1738
01:21:04,250 --> 01:21:01,679

anti-barians

1739
01:21:07,790 --> 01:21:04,260
uh

1740
01:21:10,850 --> 01:21:07,800
the holes are the positrons

1741
01:21:13,729 --> 01:21:10,860
and the particles are the electrons

1742
01:21:16,790 --> 01:21:13,739
but it could have been

1743
01:21:18,830 --> 01:21:16,800
that the positrons are the particles and

1744
01:21:20,750 --> 01:21:18,840
the holes are the electrons that is to

1745
01:21:23,229 --> 01:21:20,760
say it's totally reciprocal it's just

1746
01:21:25,550 --> 01:21:23,239
that something built the asymmetry is

1747
01:21:27,830 --> 01:21:25,560
relatively small Force but something

1748
01:21:29,090 --> 01:21:27,840
created as symmetry

1749
01:21:31,669 --> 01:21:29,100
um

1750
01:21:34,790 --> 01:21:31,679
it may sound like I'm escaping

1751
01:21:37,310 --> 01:21:34,800
uh what you wanted to get at which is

1752
01:21:40,070 --> 01:21:37,320
um uh

1753
01:21:42,770 --> 01:21:40,080
everything I do

1754
01:21:44,149 --> 01:21:42,780
is I don't know would you use the word

1755
01:21:45,410 --> 01:21:44,159
spiritual it is just trying to

1756
01:21:48,590 --> 01:21:45,420
understand

1757
01:21:51,530 --> 01:21:48,600
the resident why you know Age of Reason

1758
01:21:55,310 --> 01:21:51,540
rezon Detra what are we here for what am

1759
01:21:58,189 --> 01:21:55,320
I here for what is happening and

1760
01:22:00,410 --> 01:21:58,199
this is unfortunately the situation I'm

1761
01:22:02,870 --> 01:22:00,420
at right now the way I see it it's not

1762
01:22:05,270 --> 01:22:02,880
unlike ancient Hindu I guess

1763
01:22:07,990 --> 01:22:05,280

um that

1764
01:22:11,630 --> 01:22:08,000
uh

1765
01:22:14,270 --> 01:22:11,640
most of the universe writ large

1766
01:22:18,110 --> 01:22:14,280
may be this kind of fluctuating

1767
01:22:20,630 --> 01:22:18,120
component in which nothing special is

1768
01:22:23,229 --> 01:22:20,640
arising and then every now and again

1769
01:22:25,790 --> 01:22:23,239
there is the development of coherence

1770
01:22:28,070 --> 01:22:25,800
and coherence

1771
01:22:30,290 --> 01:22:28,080
can breed instability and that's what

1772
01:22:34,490 --> 01:22:30,300
happened in the ultra universe

1773
01:22:36,950 --> 01:22:34,500
and a way to say that is that there is a

1774
01:22:39,169 --> 01:22:36,960
bubble of Hubble perimeter that was

1775
01:22:40,790 --> 01:22:39,179
coherent so instead of it being all

1776
01:22:43,490 --> 01:22:40,800
sorts of fluctuations like this it

1777
01:22:45,229 --> 01:22:43,500
developed kind of something where this

1778
01:22:46,970 --> 01:22:45,239
was connected to this connected to this

1779
01:22:48,830 --> 01:22:46,980
and then

1780
01:22:50,689 --> 01:22:48,840
that

1781
01:22:53,270 --> 01:22:50,699
coherence

1782
01:22:56,689 --> 01:22:53,280
becomes unstable to further development

1783
01:22:59,810 --> 01:22:56,699
and so the universe that we can see

1784
01:23:02,090 --> 01:22:59,820
is that sort of entity in which there's

1785
01:23:05,330 --> 01:23:02,100
this huge degree of coherence

1786
01:23:08,510 --> 01:23:05,340
but if I were well I'm not going to bet

1787
01:23:11,810 --> 01:23:08,520
on this but I would say that the most

1788
01:23:14,030 --> 01:23:11,820

natural situation is not to have that it

1789
01:23:17,709 --> 01:23:14,040
is to have all these random things

1790
01:23:21,110 --> 01:23:17,719
happening without there being coherence

1791
01:23:24,050 --> 01:23:21,120
you know talking to each other so so so

1792
01:23:27,290 --> 01:23:24,060
that so when I guess what I'm trying to

1793
01:23:29,270 --> 01:23:27,300
say is that uh my to the extent their

1794
01:23:32,810 --> 01:23:29,280
spirituality is more a philosophical

1795
01:23:34,729 --> 01:23:32,820
spirituality uh mathematical physics

1796
01:23:36,229 --> 01:23:34,739
View

1797
01:23:40,850 --> 01:23:36,239
of

1798
01:23:43,189 --> 01:23:40,860
phenomenology in the same

1799
01:23:44,390 --> 01:23:43,199
in the same basic umbrella then there

1800
01:23:45,830 --> 01:23:44,400
was another question I can't remember

1801
01:23:49,669 --> 01:23:45,840
what that was

1802
01:23:52,669 --> 01:23:49,679
ah well you know one of the amazing

1803
01:23:54,709 --> 01:23:52,679
things is the sheer number of planets

1804
01:23:56,630 --> 01:23:54,719
that are being observed now I mean there

1805
01:23:58,669 --> 01:23:56,640
was a time when they we only had the

1806
01:24:02,270 --> 01:23:58,679
nine then we had the eight if you know

1807
01:24:05,810 --> 01:24:02,280
what I mean with Pluto uh but we have

1808
01:24:08,149 --> 01:24:05,820
this huge it is ubiquitous that there

1809
01:24:10,070 --> 01:24:08,159
are planets and

1810
01:24:12,709 --> 01:24:10,080
at least with the Earth as an example

1811
01:24:15,229 --> 01:24:12,719
which is clearly in My Views special not

1812
01:24:17,770 --> 01:24:15,239
just because we're here but because of

1813
01:24:21,470 --> 01:24:17,780

this incredible balance of how water

1814
01:24:24,169 --> 01:24:21,480
came out and is in all of its forms and

1815
01:24:27,350 --> 01:24:24,179
it's got you know uh the courage is just

1816
01:24:30,169 --> 01:24:27,360
right you know I mean it's amazing but

1817
01:24:32,990 --> 01:24:30,179
there are so many planets conditions not

1818
01:24:36,470 --> 01:24:33,000
unlike that may have happened and life

1819
01:24:39,169 --> 01:24:36,480
will choose other paths in order to

1820
01:24:41,630 --> 01:24:39,179
organize its chemistry and the

1821
01:24:44,149 --> 01:24:41,640
organization of chemistry is just so

1822
01:24:47,990 --> 01:24:44,159
amazing it's one of the things that

1823
01:24:51,169 --> 01:24:48,000
intimidates me about trying to do a toe

1824
01:24:54,350 --> 01:24:51,179
or granification it is

1825
01:24:55,870 --> 01:24:54,360
you know how this unbelievable

1826
01:24:59,510 --> 01:24:55,880
complexity

1827
01:25:03,830 --> 01:24:59,520
emerged from simplicity

1828
01:25:05,630 --> 01:25:03,840
and it's uh playing out it played out in

1829
01:25:11,570 --> 01:25:05,640
the early Universe with the development

1830
01:25:14,630 --> 01:25:11,580
of uh nucleons then nuclei then atoms

1831
01:25:17,630 --> 01:25:14,640
and then the atoms cohere but we needed

1832
01:25:21,050 --> 01:25:17,640
to make complex atoms in the furnace of

1833
01:25:23,030 --> 01:25:21,060
stars in order to create uh planets

1834
01:25:26,390 --> 01:25:23,040
which could then create life I mean it's

1835
01:25:30,649 --> 01:25:26,400
it's amazing that all of this stuff

1836
01:25:33,290 --> 01:25:30,659
was worked out and uh I guess that means

1837
01:25:35,689 --> 01:25:33,300
that mother nature is you know working

1838
01:25:38,169 --> 01:25:35,699

out our equations as we're going I don't

1839
01:25:41,570 --> 01:25:38,179
know and so that's why I don't really

1840
01:25:43,790 --> 01:25:41,580
have that view I often use the

1841
01:25:48,110 --> 01:25:43,800
terminology Mother Nature just to give

1842
01:25:50,450 --> 01:25:48,120
it uh not because I'm anthropomorphizing

1843
01:25:51,430 --> 01:25:50,460
it's just because

1844
01:25:53,990 --> 01:25:51,440
um

1845
01:25:56,689 --> 01:25:54,000
it things happen

1846
01:25:58,010 --> 01:25:56,699
that I'm not in control of

1847
01:26:05,810 --> 01:25:58,020
and

1848
01:26:08,149 --> 01:26:05,820
how she has anyway I would like to find

1849
01:26:12,169 --> 01:26:08,159
a toe so this is getting back to the

1850
01:26:15,709 --> 01:26:12,179
original thing and but the toe must have

1851
01:26:18,410 --> 01:26:15,719
Humanity fully integrated not just as

1852
01:26:21,110 --> 01:26:18,420
you know these chemical beings but as

1853
01:26:25,610 --> 01:26:21,120
chemical beings that are capable of uh

1854
01:26:28,189 --> 01:26:25,620
of creating uh and passing on

1855
01:26:30,290 --> 01:26:28,199
knowledge and information

1856
01:26:32,870 --> 01:26:30,300
and processing it

1857
01:26:34,310 --> 01:26:32,880
what's important to consider for the

1858
01:26:36,470 --> 01:26:34,320
future

1859
01:26:39,290 --> 01:26:36,480
I think that it what is probably

1860
01:26:40,669 --> 01:26:39,300
Unstoppable

1861
01:26:41,209 --> 01:26:40,679
is

1862
01:26:46,669 --> 01:26:41,219
um

1863
01:26:48,530 --> 01:26:46,679

biological entities

1864
01:26:51,229 --> 01:26:48,540
that is to say I mean we can see it

1865
01:26:53,330 --> 01:26:51,239
right I mean we have these devices but

1866
01:26:58,129 --> 01:26:53,340
uh

1867
01:27:01,430 --> 01:26:58,139
this is now as if it's part of my brain

1868
01:27:05,870 --> 01:27:01,440
right and the amount of exterior

1869
01:27:08,709 --> 01:27:05,880
information in this is outrageous and is

1870
01:27:11,330 --> 01:27:08,719
full connection and it's connecting us

1871
01:27:13,790 --> 01:27:11,340
fortunately I don't tweak but it

1872
01:27:17,810 --> 01:27:13,800
connects everybody and everybody's

1873
01:27:20,209 --> 01:27:17,820
buzzing and it's making well you know

1874
01:27:22,729 --> 01:27:20,219
the word is the hide mentality and all

1875
01:27:25,790 --> 01:27:22,739
of that and it's got pluses and it's got

1876
01:27:27,709 --> 01:27:25,800
minuses obviously they're minuses are

1877
01:27:29,750 --> 01:27:27,719
completely evident in this day and age

1878
01:27:31,310 --> 01:27:29,760
but the pluses are there as well the

1879
01:27:33,649 --> 01:27:31,320
amount of information that I can get

1880
01:27:38,209 --> 01:27:33,659
just from this thing right here and now

1881
01:27:41,270 --> 01:27:38,219
is just outrageous so then that's the um

1882
01:27:43,370 --> 01:27:41,280
integration of the machine into the

1883
01:27:46,250 --> 01:27:43,380
being of the human being

1884
01:27:49,370 --> 01:27:46,260
and that's Unstoppable no matter what

1885
01:27:50,810 --> 01:27:49,380
people say no matter you know Elon Musk

1886
01:27:53,149 --> 01:27:50,820
and others are saying oh we have to

1887
01:27:56,629 --> 01:27:53,159
worry about the development of the

1888
01:28:00,410 --> 01:27:56,639

machine life uh I don't think that we

1889
01:28:04,129 --> 01:28:00,420
can stop that that's the natural flow of

1890
01:28:06,830 --> 01:28:04,139
information and then you know if that's

1891
01:28:08,450 --> 01:28:06,840
true how did that manifest itself with

1892
01:28:09,770 --> 01:28:08,460
civilizations that are more advanced

1893
01:28:11,930 --> 01:28:09,780
than us

1894
01:28:13,189 --> 01:28:11,940
uh they will have integrated with

1895
01:28:14,810 --> 01:28:13,199
machines

1896
01:28:18,350 --> 01:28:14,820
I mean what's the difference between the

1897
01:28:21,110 --> 01:28:18,360
biological machine and a uh and a

1898
01:28:22,970 --> 01:28:21,120
mechanical machine and why wouldn't they

1899
01:28:24,950 --> 01:28:22,980
be intimately related because you know

1900
01:28:28,850 --> 01:28:24,960
you can make complex

1901
01:28:30,830 --> 01:28:28,860
um chemical things in a machine so uh

1902
01:28:33,350 --> 01:28:30,840
what is our future

1903
01:28:37,910 --> 01:28:33,360
that's just impossible we can't even say

1904
01:28:38,810 --> 01:28:37,920
it here and now in 2023 after 2023 by

1905
01:28:42,229 --> 01:28:38,820
the way

1906
01:28:44,570 --> 01:28:42,239
of what things will look like in 2050 I

1907
01:28:46,790 --> 01:28:44,580
mean you can't because it's moving so

1908
01:28:50,090 --> 01:28:46,800
fast things are integrating so fast our

1909
01:28:51,950 --> 01:28:50,100
problem is instability now I extolled

1910
01:28:55,129 --> 01:28:51,960
the virtues of instability in creating

1911
01:28:59,030 --> 01:28:55,139
universes but instability can also

1912
01:29:02,030 --> 01:28:59,040
create disasters and we are moving

1913
01:29:04,430 --> 01:29:02,040

towards a disaster which is that this

1914
01:29:06,649 --> 01:29:04,440
precious Planet it I mean I'm just

1915
01:29:09,850 --> 01:29:06,659
saying what everybody knows this

1916
01:29:12,290 --> 01:29:09,860
precious planet is being

1917
01:29:15,530 --> 01:29:12,300
transformed by human interactions

1918
01:29:17,689 --> 01:29:15,540
because we are this Collective Hive

1919
01:29:20,450 --> 01:29:17,699
that's able to make these transmissions

1920
01:29:24,290 --> 01:29:20,460
and we've got a such a large number of

1921
01:29:28,310 --> 01:29:24,300
people that it requires an incredible

1922
01:29:31,250 --> 01:29:28,320
amount of us being self-controlled and

1923
01:29:34,930 --> 01:29:31,260
able to manage as a coherent entity

1924
01:29:38,930 --> 01:29:34,940
Humanity so

1925
01:29:40,189 --> 01:29:38,940
it is you know futurologists what's a

1926
01:29:42,649 --> 01:29:40,199
futurologist

1927
01:29:45,830 --> 01:29:42,659
they don't know nobody knows because

1928
01:29:48,169 --> 01:29:45,840
it's all changing so rapidly I mean the

1929
01:29:50,629 --> 01:29:48,179
changes in my life have been amazing the

1930
01:29:53,030 --> 01:29:50,639
change that you're seeing is amazing and

1931
01:29:55,310 --> 01:29:53,040
then what's coming is either even more

1932
01:29:57,590 --> 01:29:55,320
amazing or even more disastrous it's

1933
01:30:00,770 --> 01:29:57,600
just a question of whether we can you

1934
01:30:02,570 --> 01:30:00,780
know gain control over the forces that

1935
01:30:05,689 --> 01:30:02,580
are going to try and split us all apart

1936
01:30:07,970 --> 01:30:05,699
uh so

1937
01:30:09,970 --> 01:30:07,980
if we then want to say what about the

1938
01:30:12,530 --> 01:30:09,980

theory of everything within this context

1939
01:30:13,970 --> 01:30:12,540
one way or another that's what we're

1940
01:30:17,510 --> 01:30:13,980
going to be moving towards and I think

1941
01:30:19,850 --> 01:30:17,520
it'll be based upon information Theory

1942
01:30:24,050 --> 01:30:19,860
Quantum information because that's the

1943
01:30:26,990 --> 01:30:24,060
law of the land and uh and

1944
01:30:28,129 --> 01:30:27,000
you know is it going to be from how the

1945
01:30:31,430 --> 01:30:28,139
computer

1946
01:30:34,010 --> 01:30:31,440
or is it going to be from you know one

1947
01:30:35,810 --> 01:30:34,020
or two people with their blackboards and

1948
01:30:38,229 --> 01:30:35,820
the answer is

1949
01:30:41,750 --> 01:30:38,239
probably how

1950
01:30:43,970 --> 01:30:41,760
but this is in my view much more

1951
01:30:46,070 --> 01:30:43,980
creative and fun

1952
01:30:50,030 --> 01:30:46,080
to and then the other thing that I will

1953
01:30:52,970 --> 01:30:50,040
fold into that is that

1954
01:30:55,729 --> 01:30:52,980
you know we've all been zooming our life

1955
01:30:58,370 --> 01:30:55,739
away in the last few years and that's

1956
01:31:00,169 --> 01:30:58,380
not a bad way of communicating but

1957
01:31:03,229 --> 01:31:00,179
there's something intangible about

1958
01:31:05,870 --> 01:31:03,239
humans in the same room in relatively

1959
01:31:07,189 --> 01:31:05,880
small groups interacting together but

1960
01:31:09,890 --> 01:31:07,199
basically getting

1961
01:31:14,209 --> 01:31:09,900
um intellectually hide together with

1962
01:31:18,410 --> 01:31:14,219
ideas ideas again and that

1963
01:31:20,090 --> 01:31:18,420

is precious and I guess machines can get

1964
01:31:25,550 --> 01:31:20,100
there why wouldn't they you can enhance

1965
01:31:27,950 --> 01:31:25,560
it but uh it's something which uh is not

1966
01:31:31,010 --> 01:31:27,960
reproducible over Zoom

1967
01:31:32,990 --> 01:31:31,020
so that gives hope for the biological

1968
01:31:35,030 --> 01:31:33,000
machine that there is a phenomenology

1969
01:31:37,790 --> 01:31:35,040
which is occurring which we do not

1970
01:31:39,530 --> 01:31:37,800
understand really although of course

1971
01:31:42,470 --> 01:31:39,540
many people with religion think they

1972
01:31:45,590 --> 01:31:42,480
understand it but that that's anyway so

1973
01:31:50,810 --> 01:31:45,600
future is murky

1974
01:31:52,430 --> 01:31:50,820
the podcast is now concluded thank you

1975
01:31:54,350 --> 01:31:52,440
for watching if you haven't subscribed

1976
01:31:56,330 --> 01:31:54,360
or clicked on that like button now would

1977
01:31:59,090 --> 01:31:56,340
be a great time to do so as each

1978
01:32:01,129 --> 01:31:59,100
subscribe and like helps YouTube push

1979
01:32:02,990 --> 01:32:01,139
this content to more people also I

1980
01:32:05,390 --> 01:32:03,000
recently found out that external links

1981
01:32:07,850 --> 01:32:05,400
count plenty toward the algorithm which

1982
01:32:09,110 --> 01:32:07,860
means that when you share on Twitter on

1983
01:32:11,330 --> 01:32:09,120
Facebook on Reddit

1984
01:32:13,129 --> 01:32:11,340
Etc it shows YouTube that people are

1985
01:32:15,229 --> 01:32:13,139
talking about this outside of YouTube

1986
01:32:17,090 --> 01:32:15,239
which in turn greatly AIDS the

1987
01:32:18,709 --> 01:32:17,100
Distribution on YouTube as well if you'd

1988
01:32:21,070 --> 01:32:18,719

like to support more conversations like

1989
01:32:23,090 --> 01:32:21,080
this then do consider visiting

1990
01:32:25,370 --> 01:32:23,100
theoriesofeverything.org again it's

1991
01:32:27,770 --> 01:32:25,380
support from the sponsors and you that

1992
01:32:29,450 --> 01:32:27,780
allow me to work on Tow full time you

1993
01:32:31,550 --> 01:32:29,460
get early access to ad-free audio

1994
01:32:33,649 --> 01:32:31,560
episodes there as well every dollar

1995
01:32:35,689 --> 01:32:33,659
helps far more than you may think either