

1

00:00:00,000 --> 00:00:03,417
(light electronic music)

2

00:00:09,610 --> 00:00:10,520
- Hi, everyone.

3

00:00:10,520 --> 00:00:13,450
Welcome to Conversations at the Perimeter.

4

00:00:13,450 --> 00:00:16,190
Today, Colin and I are
so excited to bring you

5

00:00:16,190 --> 00:00:18,940
this conversation with Carlo Rovelli.

6

00:00:18,940 --> 00:00:20,960
Carlo is a theoretical physicist,

7

00:00:20,960 --> 00:00:24,130
with expertise in both
physics and philosophy,

8

00:00:24,130 --> 00:00:27,120
and his research interests
include loop quantum gravity,

9

00:00:27,120 --> 00:00:28,230
the nature of time,

10

00:00:28,230 --> 00:00:31,210
and the relational
interpretation of quantum theory.

11

00:00:31,210 --> 00:00:33,230
- And Carlo is also a bestselling author

12

00:00:33,230 --> 00:00:34,720

of popular science books.

13

00:00:34,720 --> 00:00:37,090

His "Seven Brief Lessons on Physics"

14

00:00:37,090 --> 00:00:40,340

was a breakout success, sold
more than a million copies,

15

00:00:40,340 --> 00:00:43,010

has been translated into
more than 40 languages.

16

00:00:43,010 --> 00:00:44,340

I've been a fan for years,

17

00:00:44,340 --> 00:00:46,180

so it was just a thrill
for me to talk to him,

18

00:00:46,180 --> 00:00:47,500

not just about his research,

19

00:00:47,500 --> 00:00:50,020

but how and why he translates

20

00:00:50,020 --> 00:00:52,560

these difficult scientific
topics into concepts

21

00:00:52,560 --> 00:00:54,110

that people like me can understand.

22

00:00:54,110 --> 00:00:55,900

- He also has some other great books

23

00:00:55,900 --> 00:00:58,270

called "Reality Is Not What It Seems",

24

00:00:58,270 --> 00:01:00,240
there's also "The Order of Time",

25

00:01:00,240 --> 00:01:03,950
and "Helgoland: Making Sense
of the Quantum Revolution".

26

00:01:03,950 --> 00:01:05,990
And he has another new book coming out

27

00:01:05,990 --> 00:01:08,470
called "There are Places
in the World Where Rules

28

00:01:08,470 --> 00:01:10,390
Are Less Important than Kindness:

29

00:01:10,390 --> 00:01:13,227
And Other Thoughts on Physics,
Philosophy, and The World",

30

00:01:13,227 --> 00:01:15,610
and I have to say, I just love the title

31

00:01:15,610 --> 00:01:17,730
of this upcoming book, and
I can't wait to read it.

32

00:01:17,730 --> 00:01:20,180
- And I loved this conversation
that we had with Carlos,

33

00:01:20,180 --> 00:01:21,504
so let's have a listen.

34

00:01:21,504 --> 00:01:25,550
(light electronic music)

35

00:01:25,550 --> 00:01:28,650
Thank you for joining us,
it's lovely to have you here.

36
00:01:28,650 --> 00:01:31,300
- Thank you, it's wonderful
finally being back

37
00:01:31,300 --> 00:01:33,900
at the PI after this long absence.

38
00:01:33,900 --> 00:01:36,880
- I was struggling with
ways to introduce you

39
00:01:36,880 --> 00:01:38,567
to our audience because
there are so many things,

40
00:01:38,567 --> 00:01:41,050
you know, theoretical
physicist, and author,

41
00:01:41,050 --> 00:01:42,570
and world traveler, and philosopher,

42
00:01:42,570 --> 00:01:44,480
so I decided I didn't
want to introduce you.

43
00:01:44,480 --> 00:01:46,590
Pretend I'm a stranger on a
plane and I've just sat down

44
00:01:46,590 --> 00:01:48,127
next to you, and I've
buckled up, and I say,

45
00:01:48,127 --> 00:01:49,750
"Hey, what do you do for a living?"

46

00:01:49,750 --> 00:01:52,130

- I would say, "Hi, my name is Carlo.

47

00:01:52,130 --> 00:01:56,057

I was born in Italy, and I go
around and talk with people.

48

00:01:56,057 --> 00:01:58,320

I have ideas, I try to do them.

49

00:01:58,320 --> 00:01:59,262

What about you?"

50

00:01:59,262 --> 00:02:01,350

- (laughs) I talk to people like you,

51

00:02:01,350 --> 00:02:03,190

trying to figure out what
they do, so it's a good thing

52

00:02:03,190 --> 00:02:05,760

we sat next to each other on this plane.

53

00:02:05,760 --> 00:02:08,290

You didn't mention theoretical physics.

54

00:02:08,290 --> 00:02:10,330

Is that because what you consider

55

00:02:10,330 --> 00:02:12,560

yourself doing is more
just talking to people

56

00:02:12,560 --> 00:02:14,320

about a variety of subjects?

- No, if you have

57

00:02:14,320 --> 00:02:16,740
to define me, what I am primarily,

58
00:02:16,740 --> 00:02:18,670
I'm definitely a theoretical physicist.

59
00:02:18,670 --> 00:02:21,160
The rest of the things that
I do are part motivating,

60
00:02:21,160 --> 00:02:22,440
part around that.

61
00:02:22,440 --> 00:02:24,450
My competency, if I have any,

62
00:02:24,450 --> 00:02:26,120
it's in theoretical physics.

63
00:02:26,120 --> 00:02:29,120
I don't like to define myself,
even in front of myself.

64
00:02:29,120 --> 00:02:31,000
I like to keep things open.

65
00:02:31,000 --> 00:02:34,020
And when I started writing
books for the large public,

66
00:02:34,020 --> 00:02:35,757
there was a moment in
which I was telling myself,

67
00:02:35,757 --> 00:02:38,600
"Wait a moment, are you
just turning into a writer

68
00:02:38,600 --> 00:02:40,580

instead of a scientist,"

69

00:02:40,580 --> 00:02:44,300
and then I realized that this
is a meaningless question.

70

00:02:44,300 --> 00:02:47,570
I'm just doing what I'm doing,
and things are connected.

71

00:02:47,570 --> 00:02:50,450
The only meaningful question
is how many hours I devote

72

00:02:50,450 --> 00:02:52,260
for one and the other, that might be it.

73

00:02:52,260 --> 00:02:54,630
- I ask partly because you're currently,

74

00:02:54,630 --> 00:02:56,580
you have a position in London, Ontario,

75

00:02:56,580 --> 00:02:58,920
at the Rotman School of Philosophy,

76

00:02:58,920 --> 00:03:01,300
which seems, at least on the surface,

77

00:03:01,300 --> 00:03:04,297
to be a strange place for a
theoretical physicist to be.

78

00:03:04,297 --> 00:03:07,481
Can you explain what you're
doing at a school of philosophy?

79

00:03:07,481 --> 00:03:09,910
- (chuckles) I talk with philosophers.

80

00:03:09,910 --> 00:03:11,680

I love to talk with philosophers

81

00:03:11,680 --> 00:03:14,220

because I think it's useful for physics.

82

00:03:14,220 --> 00:03:17,630

I have this convention since a long time.

83

00:03:17,630 --> 00:03:20,060

I've been interested in
philosophy since I was a kid.

84

00:03:20,060 --> 00:03:21,840

When I was a student studying physics,

85

00:03:21,840 --> 00:03:24,290

I also continued to study philosophy,

86

00:03:24,290 --> 00:03:28,650

and I think that a clear-cut
separation is a bit artificial

87

00:03:28,650 --> 00:03:31,730

and is damaging for both disciplines.

88

00:03:31,730 --> 00:03:33,020

- How so?

89

00:03:33,020 --> 00:03:36,100

- Not all physics needs
to talk with philosophy.

90

00:03:36,100 --> 00:03:38,400

If you have to solve
the Maxwell's equations

91

00:03:38,400 --> 00:03:41,470
for a certain antenna, you just
happily ignore philosophers,

92
00:03:41,470 --> 00:03:43,890
and a lot of physics is just concrete,

93
00:03:43,890 --> 00:03:45,560
specific problems.
- Right.

94
00:03:45,560 --> 00:03:47,580
- But, of course, there's a
part of physics which is not

95
00:03:47,580 --> 00:03:51,430
to apply knowledge that we
have for solving problems,

96
00:03:51,430 --> 00:03:55,254
it's to find out what is the
knowledge we have at the basis,

97
00:03:55,254 --> 00:03:57,550
and that part, it's the kind
of things that, you know,

98
00:03:57,550 --> 00:04:00,320
Einstein, Maxwell, or Newton, or Galileo,

99
00:04:00,320 --> 00:04:02,970
or Boltzmann were doing, or Heisenberg,

100
00:04:02,970 --> 00:04:05,930
and that kind of activity, traditionally,

101
00:04:05,930 --> 00:04:08,630
was done by people who were
schooled in philosophy.

102

00:04:08,630 --> 00:04:11,940

I mean, Einstein had a deep
knowledge of philosophy,

103

00:04:11,940 --> 00:04:14,330

and so Heisenberg, and certainly Newton.

104

00:04:14,330 --> 00:04:17,510

Galileo, he was an avid
reader of Aristotle.

105

00:04:17,510 --> 00:04:19,490

There's a mistake in the understanding

106

00:04:19,490 --> 00:04:21,190

of physics, and science in general.

107

00:04:21,190 --> 00:04:23,050

Science is just collecting data

108

00:04:23,050 --> 00:04:25,410

and writing equations
that predict this data.

109

00:04:25,410 --> 00:04:27,960

I mean, that's just a little part of it.

110

00:04:27,960 --> 00:04:31,830

The largest part of it is figuring out

111

00:04:31,830 --> 00:04:35,590

a set of notions, concepts,
a conceptual structure,

112

00:04:35,590 --> 00:04:37,200

how to think about that.

113

00:04:37,200 --> 00:04:38,810

When you go from, you know,

114

00:04:38,810 --> 00:04:41,230
the Ptolemaic to the Copernican system,

115

00:04:41,230 --> 00:04:43,880
you don't just collect data,
you rearrange the order

116

00:04:43,880 --> 00:04:45,220
of the world in a different way.

117

00:04:45,220 --> 00:04:46,053
That's what Einstein did,

118

00:04:46,053 --> 00:04:47,130
that's what Maxwell and Faraday did,

119

00:04:47,130 --> 00:04:50,470
that's what Heisenberg did,
and Boltzmann, and so on.

120

00:04:50,470 --> 00:04:54,910
So, the core problems in
fundamental physics today,

121

00:04:54,910 --> 00:04:57,140
like quantum gravity, the
problem in which I am,

122

00:04:57,140 --> 00:05:00,330
do require the same kind of rethinking

123

00:05:00,330 --> 00:05:02,240
the conceptual basis of a discipline,

124

00:05:02,240 --> 00:05:03,850
and the philosophers
are very good in that,

125

00:05:03,850 --> 00:05:06,520

not because they solve
the problem of physics.

126

00:05:06,520 --> 00:05:08,043

I mean, relativity was found by Einstein,

127

00:05:08,043 --> 00:05:10,600

who was a physicist, but he's
a physicist who was listening

128

00:05:10,600 --> 00:05:12,750

to what the philosophers were saying.

129

00:05:12,750 --> 00:05:15,810

Philosophy has a capacity
of critical thinking,

130

00:05:15,810 --> 00:05:19,580

which is very deep, has imagination.

131

00:05:19,580 --> 00:05:21,110

Philosophers come out with
completely different ways

132

00:05:21,110 --> 00:05:23,560

of thinking about
reality, sometimes crazy,

133

00:05:23,560 --> 00:05:25,270

and we don't care about them,
but that's not the point,

134

00:05:25,270 --> 00:05:27,070

sometimes very useful.

- Sometimes I think

135

00:05:27,070 --> 00:05:29,220

theoretical physicists come
up with ideas of reality

136

00:05:29,220 --> 00:05:30,900
that strike me as crazy too.

137

00:05:30,900 --> 00:05:33,231
- Sometimes they do, sometimes
even perhaps too much crazy,

138

00:05:33,231 --> 00:05:35,127
and they should listen
to philosophers who say,

139

00:05:35,127 --> 00:05:37,250
"Wait, come on, don't exaggerate, guys."

140

00:05:37,250 --> 00:05:40,110
- Are there certain open
questions in physics

141

00:05:40,110 --> 00:05:41,870
that you think would most benefit

142

00:05:41,870 --> 00:05:44,033
from input from philosophers?

143

00:05:45,000 --> 00:05:47,500
- Yes, and they change, of course,

144

00:05:47,500 --> 00:05:51,190
because physics is a
process, and right now,

145

00:05:51,190 --> 00:05:54,840
the number of open questions
where philosophical thinking

146

00:05:54,840 --> 00:05:56,880

and philosophical clarity is useful,

147

00:05:56,880 --> 00:05:59,650
some of them, for instance,
have to do with time.

148

00:05:59,650 --> 00:06:01,830
In trying to write a
quantum theory of gravity,

149

00:06:01,830 --> 00:06:03,670
of course, space and time have to change

150

00:06:03,670 --> 00:06:05,540
because now we're looking
at the quantum property

151

00:06:05,540 --> 00:06:06,560
of space and time.

152

00:06:06,560 --> 00:06:11,016
We have so many prejudices about how space

153

00:06:11,016 --> 00:06:13,470
should be and how time should be.

154

00:06:13,470 --> 00:06:17,220
A careful philosophical
analysis of what we know,

155

00:06:17,220 --> 00:06:21,690
I find it useful, even in simple things.

156

00:06:21,690 --> 00:06:24,490
One very well-known problem about time

157

00:06:24,490 --> 00:06:27,430
is that the past is
different from the future,

158

00:06:27,430 --> 00:06:28,970
and so, what's the root

159

00:06:28,970 --> 00:06:31,010
of this difference
between past and future?

160

00:06:31,010 --> 00:06:34,550
Is that something intrinsic
in time itself, or not?

161

00:06:34,550 --> 00:06:36,560
And the answer is not just academic.

162

00:06:36,560 --> 00:06:37,700
Well, yeah, it is academic,

163

00:06:37,700 --> 00:06:40,590
but (chuckles) the question is important

164

00:06:40,590 --> 00:06:41,990
because if we want to understand more,

165

00:06:41,990 --> 00:06:44,060
understand how quantum gravity works,

166

00:06:44,060 --> 00:06:46,400
we have to get clarity about these things.

167

00:06:46,400 --> 00:06:49,380
The nature of observer is another one.

168

00:06:49,380 --> 00:06:52,260
We now are in this funny
situation with quantum mechanics,

169

00:06:52,260 --> 00:06:53,910

which is a fantastically good theory,

170

00:06:53,910 --> 00:06:57,010

but it's formulated in
terms of an observer.

171

00:06:57,010 --> 00:06:57,843

So, why?

172

00:06:57,843 --> 00:07:00,170

Do we need a guy with a PhD in physics

173

00:07:00,170 --> 00:07:02,010

to understand how the things work?

174

00:07:02,010 --> 00:07:04,580

No, I mean, things work by
themselves, without an observer,

175

00:07:04,580 --> 00:07:05,787

so how to make sense of that,

176

00:07:05,787 --> 00:07:08,040

and these are questions that physicists

177

00:07:08,040 --> 00:07:10,170

have been struggling with, and they are,

178

00:07:10,170 --> 00:07:11,630

and they will come up with a solution.

179

00:07:11,630 --> 00:07:14,170

I think solutions are being
debated around the table.

180

00:07:14,170 --> 00:07:16,580

Philosophers can listen, contribute,

181

00:07:16,580 --> 00:07:18,380
and provide perspective.

182
00:07:18,380 --> 00:07:19,387
- I have your book here,

183
00:07:19,387 --> 00:07:22,330
"Reality Is Not What It
Seems", about quantum gravity,

184
00:07:22,330 --> 00:07:23,990
and we'll get more into quantum gravity,

185
00:07:23,990 --> 00:07:28,140
but what struck me most was
the book essentially begins

186
00:07:28,140 --> 00:07:29,220
with the ancient Greeks.

187
00:07:29,220 --> 00:07:30,820
Quantum gravity and loop quantum gravity

188
00:07:30,820 --> 00:07:32,640
are relatively new fields of physics,

189
00:07:32,640 --> 00:07:35,220
but to explain them, you
went back thousands of years.

190
00:07:35,220 --> 00:07:38,070
What inspired you to go so far back

191
00:07:38,070 --> 00:07:40,483
to bring us to the present
of quantum gravity?

192
00:07:41,577 --> 00:07:43,030
- "Reality Is Not What It Seems",

193

00:07:43,030 --> 00:07:44,650
it's actually the first popular book

194

00:07:44,650 --> 00:07:45,980
that I wrote about science.

195

00:07:45,980 --> 00:07:50,697
I wrote it quite late, after
so many people had told me,

196

00:07:50,697 --> 00:07:53,240
"Why don't you write a popular
book about quantum gravity?"

197

00:07:53,240 --> 00:07:55,680
It was at least 20 years that
people were telling me that,

198

00:07:55,680 --> 00:07:57,537
and pushing, and some publishers also,

199

00:07:57,537 --> 00:07:59,850
like, "Come on, Carlo, you have

200

00:07:59,850 --> 00:08:01,610
this beautiful science, why
don't you write about that?"

201

00:08:01,610 --> 00:08:04,250
Also because people were sick
and tired with string theory,

202

00:08:04,250 --> 00:08:06,150
I mean, just can't stand
string theory anymore,

203

00:08:06,150 --> 00:08:08,120
so let's do some good quantum gravity.

204

00:08:08,120 --> 00:08:09,640
But I didn't know how to do it,

205

00:08:09,640 --> 00:08:13,030
because how do you tell quantum
gravity to people, right?

206

00:08:13,030 --> 00:08:14,787
I mean, you have to
digest general relativity,

207

00:08:14,787 --> 00:08:18,660
you have to digest quantum
mechanics, so it's a long story.

208

00:08:18,660 --> 00:08:20,897
For long, I hesitated because
I wanted to do physics

209

00:08:20,897 --> 00:08:22,560
and not waste time writing.

210

00:08:22,560 --> 00:08:24,860
Then I started considering the idea,

211

00:08:24,860 --> 00:08:27,050
but I couldn't find the right way,

212

00:08:27,050 --> 00:08:28,920
and then there was a flash.

213

00:08:28,920 --> 00:08:31,730
I had so many things to do,
but I couldn't organize them.

214

00:08:31,730 --> 00:08:33,950
I mentioned, in one of
the prefaces of my books,

215

00:08:33,950 --> 00:08:35,490
and I don't remember which edition,

216

00:08:35,490 --> 00:08:38,150
I was driving from Italy to France,

217

00:08:38,150 --> 00:08:41,320
where I had moved at the time,
in the middle of the night.

218

00:08:41,320 --> 00:08:43,257
And then I said, "Well, I
need to explain this concept,

219

00:08:43,257 --> 00:08:44,690
I need to explain this concept,

220

00:08:44,690 --> 00:08:45,920
I need to explain this concept."

221

00:08:45,920 --> 00:08:47,240
I need to tell the reader

222

00:08:47,240 --> 00:08:48,983
what is a field, an electric field.

223

00:08:48,983 --> 00:08:50,160
It's not clear.

224

00:08:50,160 --> 00:08:52,640
I need to tell the reader what
exactly we mean by geometry.

225

00:08:52,640 --> 00:08:53,473
It's subtle.

226

00:08:53,473 --> 00:08:55,800

I need to tell the reader that particles

227

00:08:55,800 --> 00:08:57,500
are not precisely particles,

228

00:08:57,500 --> 00:08:59,760
so there's some discreteness,
there's some granularity.

229

00:08:59,760 --> 00:09:01,580
And then I started thinking, well,

230

00:09:01,580 --> 00:09:04,040
maybe I should say when
these ideas were born,

231

00:09:04,040 --> 00:09:06,330
so the ideas needed to understand,

232

00:09:06,330 --> 00:09:07,980
if I tell how they were born,

233

00:09:07,980 --> 00:09:11,800
and suddenly the entire
history, the narration,

234

00:09:11,800 --> 00:09:13,100
came in front of my mind.

235

00:09:13,100 --> 00:09:16,280
I said, "Of course, I just
talk about Democritus."

236

00:09:16,280 --> 00:09:17,660
- Right.
- I talk about Galileo,

237

00:09:17,660 --> 00:09:19,510
I talk about Faraday,

I talk about Maxwell,

238

00:09:19,510 --> 00:09:22,420
what problems they were addressing,

239

00:09:22,420 --> 00:09:25,410
how they came out with
that particular solution,

240

00:09:25,410 --> 00:09:28,000
and why we're using this notion now,

241

00:09:28,000 --> 00:09:30,550
and how this notion built up, changed,

242

00:09:30,550 --> 00:09:32,589
and came all the way
to a point of reality.

243

00:09:32,589 --> 00:09:36,080
No, and this is the
evolution of the world.

244

00:09:36,080 --> 00:09:37,070
In the Renaissance,

245

00:09:37,070 --> 00:09:39,370
there's this idea that
this is res extensa.

246

00:09:39,370 --> 00:09:40,927
Then Newton comes and says,

247

00:09:40,927 --> 00:09:44,050
"Okay, I go out the world,
it's space, time passes,

248

00:09:44,050 --> 00:09:45,910
and there are some little stones

249

00:09:45,910 --> 00:09:47,340
that move around with forces."

250

00:09:47,340 --> 00:09:48,930
And then Faraday comes, "Wait, wait, wait,

251

00:09:48,930 --> 00:09:50,710
you're missing something,
there's a field,"

252

00:09:50,710 --> 00:09:53,010
okay, and Maxwell put
the order in the field.

253

00:09:53,010 --> 00:09:54,417
And then, Einstein comes and says,

254

00:09:54,417 --> 00:09:57,770
"Look, the space and the
time are actually mixed,

255

00:09:57,770 --> 00:09:59,480
so you should not have
two different things.

256

00:09:59,480 --> 00:10:00,800
You should-
- Spacetime.

257

00:10:00,800 --> 00:10:04,020
- Spacetime, and then I
instantaneously realized

258

00:10:04,020 --> 00:10:06,490
that spacetime is a field.

259

00:10:06,490 --> 00:10:08,380
Wow, okay, now we connect the notion

260

00:10:08,380 --> 00:10:09,577
of field with spacetime,

261

00:10:09,577 --> 00:10:11,620
and quantum mechanics connect the notion

262

00:10:11,620 --> 00:10:13,150
of a particle with a field.

263

00:10:13,150 --> 00:10:16,750
So, unless you go through the
way that things developed,

264

00:10:16,750 --> 00:10:18,610
you don't get them, so I
decided to write a book

265

00:10:18,610 --> 00:10:23,080
without details, but with
the core flow of ideas.

266

00:10:23,080 --> 00:10:25,570
- When that epiphany
hit you while driving,

267

00:10:25,570 --> 00:10:26,630
I know what happened after that.

268

00:10:26,630 --> 00:10:28,990
- You know what happened
after that, I got a ticket.

269

00:10:28,990 --> 00:10:30,470
- Yeah, because you were driving too fast

270

00:10:30,470 --> 00:10:32,520
'cause you were-
- I was driving too fast.

271
00:10:32,520 --> 00:10:35,470
It was an empty in the night highway.

272
00:10:35,470 --> 00:10:36,790
I was so excited,

273
00:10:36,790 --> 00:10:37,893
so excited.
- You had the pedal

274
00:10:37,893 --> 00:10:39,210
to the metal.
- Yes, the first chapter

275
00:10:39,210 --> 00:10:41,590
is gonna be saying this,
and then (imitates siren).

276
00:10:42,803 --> 00:10:43,636
I said, "Shit,"

277
00:10:43,636 --> 00:10:45,542
and then I looked at the
speedometer or whatever,

278
00:10:45,542 --> 00:10:48,020
don't know how you call it
in English, and I'm going,

279
00:10:48,020 --> 00:10:52,020
you know, 180 kilometers
per hour on the highways.

280
00:10:52,020 --> 00:10:53,200
Oh, no.

281
00:10:53,200 --> 00:10:56,447
So, I had to pull on the

side, and the policeman said,

282

00:10:56,447 --> 00:10:58,275
"What the hell are you doing,"

283

00:10:58,275 --> 00:10:59,960
and I was, you know, I just told him.

284

00:10:59,960 --> 00:11:03,140
I said, "I'm sorry, I just
was going extremely fast.

285

00:11:03,140 --> 00:11:05,450
The reality was I was not even in a hurry.

286

00:11:05,450 --> 00:11:09,200
I just got an idea how to
write a book (chuckles)

287

00:11:09,200 --> 00:11:12,800
and was so happy with that,
I just was excited, excited."

288

00:11:12,800 --> 00:11:14,120
And the policeman said, "Okay,
good luck with your book,"

289

00:11:14,120 --> 00:11:16,260
and let me go.
- He let you go.

290

00:11:16,260 --> 00:11:19,024
I'm dying to use that
excuse someday, you know.

291

00:11:19,024 --> 00:11:20,690
No, I was speeding because I figured out

292

00:11:20,690 --> 00:11:22,260

how to write a book about quantum gravity.

293

00:11:22,260 --> 00:11:23,760

I don't think it will work for me,

294

00:11:23,760 --> 00:11:25,460

but I'm glad it worked for you.

295

00:11:25,460 --> 00:11:27,577

- Yeah, it's good to know
that works. (chuckles)

296

00:11:27,577 --> 00:11:28,930

I have a question.

297

00:11:28,930 --> 00:11:30,310

A lot of what you're talking about,

298

00:11:30,310 --> 00:11:32,490

it seems that it's very fundamental,

299

00:11:32,490 --> 00:11:34,970

this idea of unlearning things,

300

00:11:34,970 --> 00:11:36,500

both when you're writing a book,

301

00:11:36,500 --> 00:11:39,650

to encourage your readers
to unlearn some things,

302

00:11:39,650 --> 00:11:41,170

or even in your research.

303

00:11:41,170 --> 00:11:43,410

I think that when we're
thinking about something,

304

00:11:43,410 --> 00:11:45,930
we can be stuck in certain
ways of conceptual thinking

305
00:11:45,930 --> 00:11:49,430
or be making some assumptions
and not even realize it.

306
00:11:49,430 --> 00:11:51,830
Are there certain strategies
that you've learned,

307
00:11:51,830 --> 00:11:53,430
perhaps from philosophers,

308
00:11:53,430 --> 00:11:55,750
that encourage you to challenge

309
00:11:55,750 --> 00:11:58,180
your conceptual ways of thinking?

310
00:11:58,180 --> 00:11:59,680
- Oh, that's a very good question.

311
00:11:59,680 --> 00:12:01,120
I don't know the answer.

312
00:12:01,120 --> 00:12:03,870
I think the most fundamental
point about learning,

313
00:12:03,870 --> 00:12:06,260
that difficulty of learning
is not to learn something new,

314
00:12:06,260 --> 00:12:08,170
that's easy, the difficulty of learning

315
00:12:08,170 --> 00:12:10,480

is to unlearn what we think we know.

316

00:12:10,480 --> 00:12:12,560

We are all deeply
convinced that we are right

317

00:12:12,560 --> 00:12:14,370

about the way (chuckles) we see the world,

318

00:12:14,370 --> 00:12:15,650

everybody, including myself,

319

00:12:15,650 --> 00:12:19,300

so we just don't give up
easily the ideas we have,

320

00:12:19,300 --> 00:12:21,472

and we don't learn unless we give up

321

00:12:21,472 --> 00:12:23,300

the ideas we have.

- You wrote once that science

322

00:12:23,300 --> 00:12:25,500

is born from an act of humility.

323

00:12:25,500 --> 00:12:26,710

Is that true?

- Yeah.

324

00:12:26,710 --> 00:12:27,730

Do you mean, by humility,

325

00:12:27,730 --> 00:12:31,220

the idea that we can accept
that we don't know everything?

326

00:12:31,220 --> 00:12:32,700

- That, but even stronger.

327

00:12:32,700 --> 00:12:35,410

The idea that what we think
we know, we might be wrong,

328

00:12:35,410 --> 00:12:38,540

and so what we don't know is so much more

329

00:12:38,540 --> 00:12:42,970

and so large that we shouldn't
rely so much on what we know.

330

00:12:42,970 --> 00:12:43,803

Yeah, I think, humility,

331

00:12:43,803 --> 00:12:47,070

there is this beautiful letter by Newton.

332

00:12:47,070 --> 00:12:49,660

Newton was arrogant, pretentious,

333

00:12:49,660 --> 00:12:52,860

perfectly aware that he
was the greatest thinker

334

00:12:52,860 --> 00:12:55,070

of his time, and three centuries later,

335

00:12:55,070 --> 00:12:56,770

we still think he's the greatest thinker,

336

00:12:56,770 --> 00:12:59,350

maybe in science, of all the times.

337

00:12:59,350 --> 00:13:00,560

He was aware of that,

338

00:13:00,560 --> 00:13:03,260

and at the end of his life,
he writes this letter.

339

00:13:03,260 --> 00:13:05,270
He says, "I don't know how
the others are looking at me

340

00:13:05,270 --> 00:13:08,000
or will be looking at me,
but I myself look at myself

341

00:13:08,000 --> 00:13:12,110
like a kid playing with
little pebbles on the shore

342

00:13:12,110 --> 00:13:15,440
in front of the ocean of our ignorance."

343

00:13:15,440 --> 00:13:17,900
That's why he succeeded
in being Newton, I think,

344

00:13:17,900 --> 00:13:19,830
because he was perfectly aware

345

00:13:19,830 --> 00:13:22,300
that there was everything
to be discovered.

346

00:13:22,300 --> 00:13:24,640
- So, he was both arrogant and humble

347

00:13:24,640 --> 00:13:25,948
at the same time.
- Humble, exactly.

348

00:13:25,948 --> 00:13:27,750
Arrogant and humble, there's a mix,

349

00:13:27,750 --> 00:13:28,727
the mixture of the two.
- Right.

350
00:13:28,727 --> 00:13:31,240
- You can be arrogant with
respect to the others,

351
00:13:31,240 --> 00:13:33,607
humble with respect to your
work and your ignorance,

352
00:13:33,607 --> 00:13:35,580
and the fact that we might be wrong.

353
00:13:35,580 --> 00:13:37,060
I've been reading this summer,

354
00:13:37,060 --> 00:13:39,590
because we're doing an
audio book in English,

355
00:13:39,590 --> 00:13:41,480
Galileo's greatest book.

356
00:13:41,480 --> 00:13:44,640
It's the dialogue of the
massive systems of the world.

357
00:13:44,640 --> 00:13:45,473
It's a fantastic book.

358
00:13:45,473 --> 00:13:48,000
It's a book that convinced
humankind, in fact,

359
00:13:48,000 --> 00:13:49,720
that the earth is moving, spinning,

360

00:13:49,720 --> 00:13:51,340
and is going around the sun.

361
00:13:51,340 --> 00:13:53,370
It has all the arguments
for the earth to move,

362
00:13:53,370 --> 00:13:56,190
but when reading it, a
surprise is that the arguments

363
00:13:56,190 --> 00:13:57,503
are just a few pages.

364
00:13:57,503 --> 00:14:01,020
A large part of the book
is to convince a reader

365
00:14:01,020 --> 00:14:05,900
that it's possible to question
what he took for granted.

366
00:14:05,900 --> 00:14:07,990
It's all about, look, you think that,

367
00:14:07,990 --> 00:14:09,720
but that might not be right.

368
00:14:09,720 --> 00:14:11,650
It's only when, three
quarters into the book,

369
00:14:11,650 --> 00:14:13,570
he said, okay, now
you're open to the book,

370
00:14:13,570 --> 00:14:14,910
I haven't argued anything.

371

00:14:14,910 --> 00:14:16,730
Only at that point, he brings argument

372
00:14:16,730 --> 00:14:18,890
for the movement of the earth,

373
00:14:18,890 --> 00:14:20,732
which, by the way, are wrong.

374
00:14:20,732 --> 00:14:22,630
- (laughs) Yeah.

375
00:14:22,630 --> 00:14:24,550
- Are mistaken, we know
that, but nevertheless,

376
00:14:24,550 --> 00:14:27,240
he convinced the world that,
not by giving good argument,

377
00:14:27,240 --> 00:14:29,680
in fact, he is wrong, but by showing

378
00:14:29,680 --> 00:14:33,990
that there's nothing wrong
in accepting that something

379
00:14:33,990 --> 00:14:36,500
completely obvious to you, it's not right.

380
00:14:36,500 --> 00:14:38,110
But that was not your question.

381
00:14:38,110 --> 00:14:41,620
Your question, well, what's
a strategy we can go to

382
00:14:42,690 --> 00:14:46,190
for not being trapped in our own beliefs,

383

00:14:46,190 --> 00:14:47,680
and I don't know.

384

00:14:47,680 --> 00:14:49,352
Scientists are like everybody else.

385

00:14:49,352 --> 00:14:50,770
- Right.
- Is it more

386

00:14:50,770 --> 00:14:53,524
than being aware of that,
keep repeating it to ourself?

387

00:14:53,524 --> 00:14:55,177
(chuckles) That, I don't
know what's the right way

388

00:14:55,177 --> 00:14:57,200
of doing so.
- Yeah.

389

00:14:57,200 --> 00:14:59,650
- Do you remember a moment
in your earlier life

390

00:14:59,650 --> 00:15:01,860
when maybe physics, or science itself,

391

00:15:01,860 --> 00:15:04,450
sort of revealed to you
this new way of looking

392

00:15:04,450 --> 00:15:06,730
or unlearning things you may have known

393

00:15:06,730 --> 00:15:08,470
and opened your eyes to new possibilities?

394

00:15:08,470 --> 00:15:10,290

Was there an epiphany there,

395

00:15:10,290 --> 00:15:12,967

or was it a series of happenings?

396

00:15:12,967 --> 00:15:14,750

- It was a series of happenings,

397

00:15:14,750 --> 00:15:18,320

starting from when I was a student.

398

00:15:18,320 --> 00:15:20,660

I fell in love with science late,

399

00:15:20,660 --> 00:15:24,090

when I was already a
university student in physics.

400

00:15:24,090 --> 00:15:28,100

In studying modern physics,
it was a series of shocks,

401

00:15:28,100 --> 00:15:31,160

like, oh, my God, somehow
reality is not what it seems.

402

00:15:31,160 --> 00:15:32,730

That became the title of my book.

403

00:15:32,730 --> 00:15:35,250

So, it was a strong
experience at that time.

404

00:15:35,250 --> 00:15:37,800

- Is that a phrase that
you've had in your mind

405
00:15:37,800 --> 00:15:39,360
for a long time before the book came out,

406
00:15:39,360 --> 00:15:40,910
that reality is not what it seems?

407
00:15:40,910 --> 00:15:44,400
Is that sort of the realization
you had those years ago?

408
00:15:44,400 --> 00:15:46,470
- The concept, yes.
- Yeah.

409
00:15:46,470 --> 00:15:50,440
- For sure, somehow it grew
with me in various manners.

410
00:15:50,440 --> 00:15:51,700
The phrase itself, I'm not sure.

411
00:15:51,700 --> 00:15:53,540
I think it came from the text of the book,

412
00:15:53,540 --> 00:15:56,460
and then I picked it up
because it represented

413
00:15:56,460 --> 00:15:58,170
what was going on.

414
00:15:58,170 --> 00:15:59,850
- You mentioned quantum gravity before,

415
00:15:59,850 --> 00:16:01,377
and there's a line in your book,

416
00:16:01,377 --> 00:16:03,020

"Seven Brief Lessons on Physics".

417

00:16:03,020 --> 00:16:05,117

It's just such a simple short line,

418

00:16:05,117 --> 00:16:08,020

"There is a paradox at the heart of our understanding

419

00:16:08,020 --> 00:16:09,360

of the physical world."

420

00:16:09,360 --> 00:16:11,080

That paradox is essentially, I think,

421

00:16:11,080 --> 00:16:12,640

the root of quantum gravity,

422

00:16:12,640 --> 00:16:15,720

that paradox between general relativity

423

00:16:15,720 --> 00:16:17,080

and quantum mechanics.

424

00:16:17,080 --> 00:16:20,480

Can you elaborate a bit more on why that's a paradox,

425

00:16:20,480 --> 00:16:22,570

what paradox we're struggling with,

426

00:16:22,570 --> 00:16:24,910

and why we need a solution to it?

427

00:16:24,910 --> 00:16:27,600

- I believe it is an apparent paradox,

428

00:16:27,600 --> 00:16:31,570

that it's strikingly
paradoxical, the way it looks.

429

00:16:31,570 --> 00:16:35,450
It's what a student of physics learns

430

00:16:35,450 --> 00:16:38,600
when he goes to school at the university

431

00:16:38,600 --> 00:16:41,310
and he just minimally thinks,

432

00:16:41,310 --> 00:16:44,470
because you go to classes
on quantum mechanics

433

00:16:44,470 --> 00:16:46,660
and you get your explanation of the world,

434

00:16:46,660 --> 00:16:49,020
and the world is all about discreteness.

435

00:16:49,020 --> 00:16:52,280
Light is photons, and it's
just discrete particles.

436

00:16:52,280 --> 00:16:54,470
They're minute particle bits of things.

437

00:16:54,470 --> 00:16:56,600
Everything is in bits and chunks.

438

00:16:56,600 --> 00:16:57,910
It's probabilistic.

439

00:16:57,910 --> 00:17:00,130
There is this strange,

440

00:17:00,130 --> 00:17:03,420
interactive thing from
which, in quantum mechanics,

441
00:17:03,420 --> 00:17:05,870
you predict how things
interact with one another.

442
00:17:05,870 --> 00:17:08,370
So, you say, okay, that's
the way reality is.

443
00:17:08,370 --> 00:17:11,130
I mean, okay, God did
reality like that, I mean,

444
00:17:11,130 --> 00:17:13,540
we don't know what she thinks or why,

445
00:17:13,540 --> 00:17:14,570
but that's the way reality is.

446
00:17:14,570 --> 00:17:16,210
And then you go to the other class,

447
00:17:16,210 --> 00:17:18,000
with this other teacher that teaches you

448
00:17:18,000 --> 00:17:19,920
about general relativity,
and this is, you know,

449
00:17:19,920 --> 00:17:23,270
an equally immense,
fundamental, successful theory,

450
00:17:23,270 --> 00:17:25,460
and the universe is perfectly continuous.

451

00:17:25,460 --> 00:17:27,220
There's nothing probabilistic,

452
00:17:27,220 --> 00:17:29,260
deterministic equations of motion.

453
00:17:29,260 --> 00:17:32,190
Everything is perfectly
objective out there.

454
00:17:32,190 --> 00:17:35,800
You can write the history of
spacetime in a single equation.

455
00:17:35,800 --> 00:17:36,910
And then I think, wait a minute.

456
00:17:36,910 --> 00:17:39,130
I mean, either one or the
other, there cannot be, I mean,

457
00:17:39,130 --> 00:17:41,584
my teachers stopped
talking to one another,

458
00:17:41,584 --> 00:17:44,110
(chuckles) haven't talked
to one another for 30 years.

459
00:17:44,110 --> 00:17:46,730
So, it's really two
totally different images

460
00:17:46,730 --> 00:17:49,210
of how reality works.

461
00:17:49,210 --> 00:17:51,220
God can be complicated, I don't know,

462

00:17:51,220 --> 00:17:53,230
but not so self-contradictory.

463
00:17:53,230 --> 00:17:55,540
The world is either this
way or the other way,

464
00:17:55,540 --> 00:17:57,950
or some way which is compatible with both.

465
00:17:57,950 --> 00:17:59,013
- And is that the question

466
00:17:59,013 --> 00:17:59,920
of quantum gravity?
- That's quantum gravity.

467
00:17:59,920 --> 00:18:02,700
Exactly.
- Speaking of quantum gravity,

468
00:18:02,700 --> 00:18:03,660
as part of this show,

469
00:18:03,660 --> 00:18:06,080
we collect questions from other listeners,

470
00:18:06,080 --> 00:18:09,860
and a mutual friend of
ours, Carlo, Lin-Qing Chen,

471
00:18:09,860 --> 00:18:12,610
she's a postdoctoral researcher
in Brussels, Belgium,

472
00:18:12,610 --> 00:18:14,420
she sent in a question for you.

473
00:18:14,420 --> 00:18:15,360

- Oh, fantastic.

474

00:18:15,360 --> 00:18:17,380
- Hi, Carlo, this is Lin-Qing.

475

00:18:17,380 --> 00:18:21,550
So, in our quest for a
theory of quantum gravity,

476

00:18:21,550 --> 00:18:25,880
do you think we will need
new fundamental principles

477

00:18:25,880 --> 00:18:29,660
that both quantum mechanics
or general relativity

478

00:18:29,660 --> 00:18:32,400
have not yet revealed to us,

479

00:18:32,400 --> 00:18:36,010
and what is your strategy
for finding them out?

480

00:18:36,010 --> 00:18:37,410
Thank you.

481

00:18:37,410 --> 00:18:40,020
- The answer I have, I'm not sure,

482

00:18:40,020 --> 00:18:43,140
but that answer on
which I'm working is no.

483

00:18:43,140 --> 00:18:44,070
No to the question, do you think

484

00:18:44,070 --> 00:18:48,320
there is some fundamental

principle that we'll be missing?

485

00:18:48,320 --> 00:18:50,040

I think that the idea that, oh,

486

00:18:50,040 --> 00:18:51,890

we are missing something crucial,

487

00:18:51,890 --> 00:18:54,630

fundamental down there is just wrong.

488

00:18:54,630 --> 00:18:57,610

The point is that we have to
take seriously what we learn

489

00:18:57,610 --> 00:19:00,500

with quantum mechanics and
seriously what we learn

490

00:19:00,500 --> 00:19:03,280

about general relativity,
and bring them together,

491

00:19:03,280 --> 00:19:04,950

and they do go together.

492

00:19:04,950 --> 00:19:07,750

I'm a very conservative
guy from this perspective.

493

00:19:07,750 --> 00:19:10,320

I don't believe we need something new,

494

00:19:10,320 --> 00:19:13,730

a supersymmetry with other
worlds, many dimensions,

495

00:19:13,730 --> 00:19:15,360

breaking the Lorentz invariance,

496

00:19:15,360 --> 00:19:17,780
of correction to quantum mechanics.

497

00:19:17,780 --> 00:19:21,290
Nature has been saying
no to all the attempts

498

00:19:21,290 --> 00:19:24,050
to test this alternative
hypothesis so far,

499

00:19:24,050 --> 00:19:27,330
so I don't see any evidence
that we're missing something.

500

00:19:27,330 --> 00:19:29,840
General relativity, it's about spacetime,

501

00:19:29,840 --> 00:19:31,485
so it's a shape of spacetime,

502

00:19:31,485 --> 00:19:33,310
a shape of space and a shape of time,

503

00:19:33,310 --> 00:19:34,970
which means how different
clocks move with respect

504

00:19:34,970 --> 00:19:38,700
to one another and how
meters measure jobs,

505

00:19:38,700 --> 00:19:41,810
and that's quantum, and
so we have to understand

506

00:19:41,810 --> 00:19:43,717
the quantum properties of time

507

00:19:43,717 --> 00:19:46,080
and the quantum property of space.

508

00:19:46,080 --> 00:19:47,130
That's radical.

509

00:19:47,130 --> 00:19:49,980
So, the assumption is
conservative, but if you follow up,

510

00:19:49,980 --> 00:19:51,910
this is completely
radical because it means

511

00:19:51,910 --> 00:19:54,460
this continuous space
that you thought it was,

512

00:19:54,460 --> 00:19:55,760
forget about it.

513

00:19:55,760 --> 00:19:58,890
The time evolution in a single
variable, forget about it.

514

00:19:58,890 --> 00:20:01,700
You have to replace the
usual way of thinking space,

515

00:20:01,700 --> 00:20:03,480
the usual way of thinking time

516

00:20:03,480 --> 00:20:05,850
with something consistent
with quantum mechanics,

517

00:20:05,850 --> 00:20:08,140
but not this quantum

mechanics in spacetime,

518

00:20:08,140 --> 00:20:09,600
quantum mechanics of spacetime.

519

00:20:09,600 --> 00:20:12,340
So, for instance, you
have to have mathematics

520

00:20:12,340 --> 00:20:14,900
and a physical intuition that allows you

521

00:20:14,900 --> 00:20:18,670
for having quantum
superposition of spacetimes,

522

00:20:18,670 --> 00:20:20,010
plural, of geometries.

523

00:20:20,010 --> 00:20:22,990
Like, there is shooting a
cat that can be both awake

524

00:20:22,990 --> 00:20:25,180
and asleep, or somebody
said dead and alive.

525

00:20:25,180 --> 00:20:26,600
- I like your version better.
- (laughs) Yeah.

526

00:20:26,600 --> 00:20:28,347
- I like cats, so.
- Yeah, exactly.

527

00:20:28,347 --> 00:20:30,750
So, shooting a cat in quantum mechanics

528

00:20:30,750 --> 00:20:33,290

is it can be both awake and sleeping.

529

00:20:33,290 --> 00:20:35,100

And so, in the same sense,

530

00:20:35,100 --> 00:20:37,140

space can have a shape

and also another shape

531

00:20:37,140 --> 00:20:38,173

in a superposition of the two,

532

00:20:38,173 --> 00:20:41,450

and, of course, this requires imagination,

533

00:20:41,450 --> 00:20:43,940

finding the right concept

to talk about that.

534

00:20:43,940 --> 00:20:46,200

That's also where

philosophy comes in useful,

535

00:20:46,200 --> 00:20:47,920

and the right mathematics,

536

00:20:47,920 --> 00:20:49,410

and I think there are, I mean,

537

00:20:49,410 --> 00:20:51,430

loop quantum gravity is

an example of a theory

538

00:20:51,430 --> 00:20:52,680

that attempts to do that.

539

00:20:52,680 --> 00:20:54,100

We don't know if it is right.

540
00:20:54,100 --> 00:20:55,670
It's very conservative,

541
00:20:55,670 --> 00:20:58,530
and that's why the answer to
Lin-Qing's question is no.

542
00:20:58,530 --> 00:21:01,592
So, there's no other
principle to be added,

543
00:21:01,592 --> 00:21:04,190
but it's completely radical
then because it forces us

544
00:21:04,190 --> 00:21:06,710
to rethink the basic notions.

545
00:21:06,710 --> 00:21:08,970
- And you mentioned evidence
when you were giving

546
00:21:08,970 --> 00:21:11,020
this explanation, looking for evidence

547
00:21:11,020 --> 00:21:13,560
to support various theories
of quantum gravity.

548
00:21:13,560 --> 00:21:16,480
What kind of evidence
would you be looking for?

549
00:21:16,480 --> 00:21:18,800
- Recently, there has
been a lot of evidence

550
00:21:18,800 --> 00:21:21,730
that helps us, and in science,

551

00:21:21,730 --> 00:21:26,130
evidence is never definitive,
it's always indications,

552

00:21:26,130 --> 00:21:29,050
like in life, by the way. (laughs)

553

00:21:29,050 --> 00:21:30,410
It's not that you kill a theory.

554

00:21:30,410 --> 00:21:33,220
It's very rarely that you
really, really kill a theory

555

00:21:33,220 --> 00:21:36,200
with an experiment, but you
create problems to a theory,

556

00:21:36,200 --> 00:21:37,810
and when a theory has too many problems,

557

00:21:37,810 --> 00:21:39,010
you look somewhere else,

558

00:21:39,010 --> 00:21:40,830
and there have been a lot
of these things recently.

559

00:21:40,830 --> 00:21:44,010
The strongest and the most
unexpected for many people

560

00:21:44,010 --> 00:21:46,200
has been the absence of
low-energy supersymmetry.

561

00:21:46,200 --> 00:21:48,470
There was a big part of the community

562

00:21:48,470 --> 00:21:52,540

that was completely
convinced, sort of 99.9%,

563

00:21:52,540 --> 00:21:55,430

that supersymmetry was
going to be detected-

564

00:21:55,430 --> 00:21:56,390

- By the Large Hadron Collider?

565

00:21:56,390 --> 00:21:57,686

- At CERN, right.
- Yeah.

566

00:21:57,686 --> 00:21:58,769

- It was LHC,

567

00:21:59,780 --> 00:22:01,330

and it wasn't.

568

00:22:01,330 --> 00:22:03,460

It was a shock, there were
titles of the journals,

569

00:22:03,460 --> 00:22:05,290

like, you know, this
is a crisis of physics.

570

00:22:05,290 --> 00:22:07,090

Of course, it's not the crisis of physics.

571

00:22:07,090 --> 00:22:09,080

It's only the crisis for
those who expected it,

572

00:22:09,080 --> 00:22:09,913

which is not physics,

573
00:22:09,913 --> 00:22:11,610
it's just a particular school of thought.

574
00:22:11,610 --> 00:22:13,060
But that's nature talking,

575
00:22:13,060 --> 00:22:14,530
and when nature is
talking, we should listen.

576
00:22:14,530 --> 00:22:17,430
Another example is breaking
the Lorentz invariance,

577
00:22:17,430 --> 00:22:20,270
the symmetry at the basis of
Einstein special relativity,

578
00:22:20,270 --> 00:22:21,750
which is Lorentz invariance.

579
00:22:21,750 --> 00:22:23,960
Some people thought, also,
that was like supersymmetry.

580
00:22:23,960 --> 00:22:25,850
It was a very nice idea.

581
00:22:25,850 --> 00:22:29,140
You can make the point
of quantum gravity easier

582
00:22:29,140 --> 00:22:30,660
if you don't have Lorentz invariance.

583
00:22:30,660 --> 00:22:32,470
So, people try to provide theories

584
00:22:32,470 --> 00:22:33,780
which break Lorentz invariance

585
00:22:33,780 --> 00:22:36,580
and might be quantum gravity theories.

586
00:22:36,580 --> 00:22:37,870
So, this was tested,

587
00:22:37,870 --> 00:22:40,460
15 years now of
astrophysical observations,

588
00:22:40,460 --> 00:22:42,530
and all the expected signs

589
00:22:42,530 --> 00:22:44,610
of breaking Lorentz invariance, zero.

590
00:22:44,610 --> 00:22:46,480
Once again, nature talks.

591
00:22:46,480 --> 00:22:48,850
As far as we know, nature is
saying, "No, no, no, no, guys,

592
00:22:48,850 --> 00:22:50,610
that's not the right way
to look for the solution."

593
00:22:50,610 --> 00:22:52,370
So, I think nature is
giving indication, I mean,

594
00:22:52,370 --> 00:22:55,330
a lot of people expect a
negative cosmological constant.

595

00:22:55,330 --> 00:22:57,400
Even today, there is a
large part of the community

596
00:22:57,400 --> 00:22:59,670
that continues to do
calculations and calculations

597
00:22:59,670 --> 00:23:02,446
and calculations with a
negative cosmological constant,

598
00:23:02,446 --> 00:23:03,940
or AdS/CFT.

599
00:23:03,940 --> 00:23:07,010
AdS means anti-de Sitter,
which means there's a space

600
00:23:07,010 --> 00:23:09,520
with an effective negative
cosmological constant,

601
00:23:09,520 --> 00:23:11,410
and you accept that the
cosmological constant

602
00:23:11,410 --> 00:23:13,990
has been measured by the
astronomers, by the cosmologists.

603
00:23:13,990 --> 00:23:15,840
In a very convincing way,
they got the Nobel Prize,

604
00:23:15,840 --> 00:23:18,400
the ones who did that, and it's positive.

605
00:23:18,400 --> 00:23:21,670
So, once again, I think my interpretation,

606

00:23:21,670 --> 00:23:24,327
my reading of that as a scientist,
I mean, I might be wrong,

607

00:23:24,327 --> 00:23:27,910
but my reading of that is that
nature is talking, listen.

608

00:23:27,910 --> 00:23:28,940
That's not the right direction.

609

00:23:28,940 --> 00:23:30,910
- How will nature speak to you to advance

610

00:23:30,910 --> 00:23:32,710
loop quantum gravity, say.

611

00:23:32,710 --> 00:23:34,360
- There are two or three directions

612

00:23:34,360 --> 00:23:37,720
where me and many of my
colleagues are looking into.

613

00:23:37,720 --> 00:23:39,160
For the moment, zero,

614

00:23:39,160 --> 00:23:42,820
so we have no negative
response from nature,

615

00:23:42,820 --> 00:23:44,469
but we don't have any positive response

616

00:23:44,469 --> 00:23:46,300
(laughing) from nature.
- Can you explain that a bit?

617

00:23:46,300 --> 00:23:49,170

- We don't know, so there's
nothing that has come

618

00:23:49,170 --> 00:23:52,010

as a contradiction to what we expected,

619

00:23:52,010 --> 00:23:53,670

but there's nothing that has come

620

00:23:53,670 --> 00:23:55,950

to confirm predictions
of the theory either,

621

00:23:55,950 --> 00:23:57,197

so I cannot say that quantum gravity

622

00:23:57,197 --> 00:23:59,010

is confirmed in any sense.

623

00:23:59,010 --> 00:24:01,510

So, where could the
confirmation come from?

624

00:24:01,510 --> 00:24:02,910

I see three possible directions.

625

00:24:02,910 --> 00:24:04,550

One is the early cosmology.

626

00:24:04,550 --> 00:24:07,470

There's a lot of literature,
papers, and papers written.

627

00:24:07,470 --> 00:24:10,580

So, the universe, we know,
came out in the Big Bang,

628

00:24:10,580 --> 00:24:14,040
the very early moment, at
the beginning of its life,

629
00:24:14,040 --> 00:24:16,260
deep into quantum gravity regime,

630
00:24:16,260 --> 00:24:18,930
so that's where quantum
gravity should appear.

631
00:24:18,930 --> 00:24:21,890
A lot of colleagues have
applied loop quantum gravity

632
00:24:21,890 --> 00:24:23,830
to describe what happens there.

633
00:24:23,830 --> 00:24:26,580
It seems to be working, and to see if one

634
00:24:26,580 --> 00:24:29,180
can predict effects of what happened there

635
00:24:29,180 --> 00:24:32,000
that can be tested in the
cosmic background radiation,

636
00:24:32,000 --> 00:24:35,330
it's possible, measurements
getting more precise.

637
00:24:35,330 --> 00:24:37,150
I hope they will convert
it with something useful,

638
00:24:37,150 --> 00:24:38,230
but for the moment, there's nothing.

639

00:24:38,230 --> 00:24:40,320
That's one, the second one is black holes.

640
00:24:40,320 --> 00:24:41,700
I'm working on black holes.

641
00:24:41,700 --> 00:24:44,080
Loop quantum gravity is
consistent very much with the idea

642
00:24:44,080 --> 00:24:46,260
that a black hole evaporates.

643
00:24:46,260 --> 00:24:48,780
That's Hawking's realization,
that black holes evaporate.

644
00:24:48,780 --> 00:24:51,490
They become smaller, smaller,
smaller, and then, at the end,

645
00:24:51,490 --> 00:24:54,080
they don't just disappear,
pop out of existence,

646
00:24:54,080 --> 00:24:56,350
but there's a remnant,
which is a white hole.

647
00:24:56,350 --> 00:24:59,400
So, there's a quantum
gravity transition jump

648
00:24:59,400 --> 00:25:01,740
from a black hole to a white
hole, with a little throat,

649
00:25:01,740 --> 00:25:03,900
but a huge inside.

650

00:25:03,900 --> 00:25:06,467

And then this white hole,
slowly, things come out,

651

00:25:06,467 --> 00:25:08,740

where the information slowly comes out,

652

00:25:08,740 --> 00:25:10,250

lives for a very long time.

653

00:25:10,250 --> 00:25:11,480

So, this is a scenario,

654

00:25:11,480 --> 00:25:14,190

it might have astrophysical consequences.

655

00:25:14,190 --> 00:25:16,370

These have been explored by this group,

656

00:25:16,370 --> 00:25:18,593

including London and the
people I'm working with.

657

00:25:18,593 --> 00:25:20,750

There's one of these possibilities,

658

00:25:20,750 --> 00:25:22,710

which I'm particularly attracted to,

659

00:25:22,710 --> 00:25:25,340

which is that these little
things that float around

660

00:25:25,340 --> 00:25:28,700

in the universe are actually dark matter,

661

00:25:28,700 --> 00:25:30,460

or a component of dark matter.

662

00:25:30,460 --> 00:25:32,780
If so, it might be that we have
already observed something,

663

00:25:32,780 --> 00:25:34,210
we just haven't recognized it.

664

00:25:34,210 --> 00:25:36,450
- Dark matter being another great puzzle

665

00:25:36,450 --> 00:25:38,030
of modern physics.
- Dark matter,

666

00:25:38,030 --> 00:25:40,320
it's a big puzzle, and that's the opposite

667

00:25:40,320 --> 00:25:42,300
of the quantum gravity puzzle,
because it's not a puzzle

668

00:25:42,300 --> 00:25:45,230
in our understanding, it's
a puzzle in what we see.

669

00:25:45,230 --> 00:25:47,270
You look at the universe around us

670

00:25:47,270 --> 00:25:50,260
and we see galaxies,
stars, clouds of hydrogen,

671

00:25:50,260 --> 00:25:53,540
all sorts of stuff, and then
there is this stuff out there,

672

00:25:53,540 --> 00:25:55,490
something that produces effect out there.

673

00:25:55,490 --> 00:25:58,090

We see the gravitational
effect of these things.

674

00:25:58,090 --> 00:25:59,790

We have quite convincing evidence

675

00:25:59,790 --> 00:26:01,013

that it's not usual matter.

676

00:26:01,013 --> 00:26:03,780

It's not just atoms or
molecules or protons

677

00:26:03,780 --> 00:26:06,190

or neutrinos or photons,

678

00:26:06,190 --> 00:26:08,133

it's something else, and it's a lot.

679

00:26:08,133 --> 00:26:10,880

There's quite as much normal
matter and dark matter,

680

00:26:10,880 --> 00:26:13,880

even more dark matter, and
nobody knows what it is,

681

00:26:13,880 --> 00:26:15,240

so it's fantastic.

682

00:26:15,240 --> 00:26:17,740

People who say that we're
close to the end of physics

683

00:26:17,740 --> 00:26:19,920

and close to the theory of
everything, come on, guys,

684

00:26:19,920 --> 00:26:21,750

we don't even know what we see around us.

685

00:26:21,750 --> 00:26:23,740

So, dark matter is really
an important question.

686

00:26:23,740 --> 00:26:25,940

We have a lot of possible explanations,

687

00:26:25,940 --> 00:26:29,530

but many are non, confirmed
non, really, credible.

688

00:26:29,530 --> 00:26:31,180

I like the black hole ones

689

00:26:31,180 --> 00:26:35,270

because it does not rely
on any new assumption.

690

00:26:35,270 --> 00:26:36,503

Well, if there's black holes,

691

00:26:36,503 --> 00:26:38,260

it's just nothing we know exists.

692

00:26:38,260 --> 00:26:40,190

- It's funny, you said it's a mystery,

693

00:26:40,190 --> 00:26:42,240

we don't know, and that's fantastic.

694

00:26:42,240 --> 00:26:44,320

That's not always the case
in a lot of professions,

695

00:26:44,320 --> 00:26:46,027
where the lack of
knowledge about something

696
00:26:46,027 --> 00:26:47,890
is something you're excited about.

697
00:26:47,890 --> 00:26:51,180
Are you glad that physics is
nowhere near being complete?

698
00:26:51,180 --> 00:26:52,677
- Oh, infinitely so, of course,

699
00:26:52,677 --> 00:26:54,980
otherwise it would be boring, right?

700
00:26:54,980 --> 00:26:58,180
Imagine what a disaster if
somebody wrote, "Okay, I got it,

701
00:26:58,180 --> 00:27:00,380
everything, this is the final
equation of everything."

702
00:27:00,380 --> 00:27:01,277
- But that's what you're going for.

703
00:27:01,277 --> 00:27:02,110
- No.
- No?

704
00:27:02,110 --> 00:27:04,040
- No, zero.
- Is quantum gravity

705
00:27:04,040 --> 00:27:07,690
not sort of that grand, unifying theory?

706

00:27:07,690 --> 00:27:09,113
- No, it's a step on the way.

707
00:27:09,113 --> 00:27:11,280
It's just figuring out what
is the quantum property

708
00:27:11,280 --> 00:27:12,460
of space and time.

709
00:27:12,460 --> 00:27:14,800
I'm not working for
material of everything,

710
00:27:14,800 --> 00:27:16,250
I'm working just for a next step

711
00:27:16,250 --> 00:27:17,440
in understanding what's around.

712
00:27:17,440 --> 00:27:20,600
- Once we've figured out the
quantum nature of spacetime,

713
00:27:20,600 --> 00:27:23,760
does that open up new questions
or help us answer old ones?

714
00:27:23,760 --> 00:27:27,540
- I suppose loop quantum
gravity is confirmed.

715
00:27:27,540 --> 00:27:29,490
With a colleague, Marios Christodoulou,

716
00:27:29,490 --> 00:27:31,800
we have an experiment which we proposed,

717
00:27:31,800 --> 00:27:34,960

which might even be
doable in 10 years or so,

718

00:27:34,960 --> 00:27:37,580

which would actually test
the discreteness of time

719

00:27:37,580 --> 00:27:38,767

predicted by loop quantum gravity.

720

00:27:38,767 --> 00:27:40,990

So, suppose this can be done, and bingo,

721

00:27:40,990 --> 00:27:43,530

the right numbers, because
loop quantum gravity

722

00:27:43,530 --> 00:27:45,400

predicts that space is discrete, right?

723

00:27:45,400 --> 00:27:48,260

It's granular, like
light is made by photons,

724

00:27:48,260 --> 00:27:51,320

spaces make this grain
of space, but also time,

725

00:27:51,320 --> 00:27:53,350

I expect it has this granularity.

726

00:27:53,350 --> 00:27:55,160

We have an idea of, perhaps,

727

00:27:55,160 --> 00:27:57,290

with some slight advances in technology,

728

00:27:57,290 --> 00:27:59,422

not excessive, it could be tested.

729

00:27:59,422 --> 00:28:01,510

Now, suppose this comes out right.

730

00:28:01,510 --> 00:28:03,320

Loop quantum gravity is correct, perfect,

731

00:28:03,320 --> 00:28:05,627

the right numbers are there, now what?

732

00:28:05,627 --> 00:28:08,360

Well, now we still have a universe

733

00:28:08,360 --> 00:28:11,070

described by a funny standard model,

734

00:28:11,070 --> 00:28:14,110

where the weak interactions

and the strong interactions

735

00:28:14,110 --> 00:28:17,330

are completely separated,

described by similar theories,

736

00:28:17,330 --> 00:28:19,570

but not really unified in any way.

737

00:28:19,570 --> 00:28:22,470

Gravity described by still another theory.

738

00:28:22,470 --> 00:28:24,560

19 parameters for the standard model.

739

00:28:24,560 --> 00:28:26,420

Who chose them? Why?

740

00:28:26,420 --> 00:28:28,340

Three generations.

741

00:28:28,340 --> 00:28:31,400

Suppose with quantum gravity,
we figure out the Big Bang,

742

00:28:31,400 --> 00:28:32,863

and what seems likely is that it was not,

743

00:28:32,863 --> 00:28:34,940

that the initial exposure was a bounce.

744

00:28:34,940 --> 00:28:36,900

It's an idea studied by various people.

745

00:28:36,900 --> 00:28:38,160

- That our universe is the result

746

00:28:38,160 --> 00:28:40,580

of a previous one collapsing
and expanding again?

747

00:28:40,580 --> 00:28:42,970

- Some universe was
collapsing, in some sense,

748

00:28:42,970 --> 00:28:44,140

under its own weight.

749

00:28:44,140 --> 00:28:46,350

It gets to the sort of
maximum compression,

750

00:28:46,350 --> 00:28:47,660

where quantum gravity comes in.

751

00:28:47,660 --> 00:28:49,410

It bounces, and then what we see

752

00:28:49,410 --> 00:28:51,510
as the Big Bang is this bounce.

753
00:28:51,510 --> 00:28:53,450
I think it's a reasonable hypothesis.

754
00:28:53,450 --> 00:28:56,550
It seems to be more
reasonable than the Big Bang.

755
00:28:56,550 --> 00:28:58,490
Suppose we figured this out.

756
00:28:58,490 --> 00:28:59,720
Have we solved everything?

757
00:28:59,720 --> 00:29:00,810
No, of course, I mean,

758
00:29:00,810 --> 00:29:04,182
where was the collapsing
universe coming from?

759
00:29:04,182 --> 00:29:06,210
(chuckles) I mean, what was there?

760
00:29:06,210 --> 00:29:10,640
It seems, today, so impossibly
difficult to figure out

761
00:29:10,640 --> 00:29:12,510
what was in the collapsing universe,

762
00:29:12,510 --> 00:29:14,440
but at the time of my great-grandfather,

763
00:29:14,440 --> 00:29:16,820
it seemed impossible to discover

764

00:29:16,820 --> 00:29:19,230

what was the chemical
composition of Jupiter.

765

00:29:19,230 --> 00:29:21,780

I mean, it was considered
an unsolvable problem.

766

00:29:21,780 --> 00:29:23,910

I mean, now we know,
in Jupiter, everything,

767

00:29:23,910 --> 00:29:25,990

even, you know, if there were ants there,

768

00:29:25,990 --> 00:29:26,823

we would've seen that.

769

00:29:26,823 --> 00:29:31,720

So, science finds new problems
and grows at all levels

770

00:29:31,720 --> 00:29:34,600

if the mystery is not a reason of sadness,

771

00:29:34,600 --> 00:29:37,923

it's a reason of joy because
a new thing's discovered.

772

00:29:37,923 --> 00:29:39,890

It's the beauty of understanding.

773

00:29:39,890 --> 00:29:41,360

- You're still, like Isaac Newton,

774

00:29:41,360 --> 00:29:44,115

playing with pebbles on the
vast sea of what we don't know?

775

00:29:44,115 --> 00:29:46,550

- Absolutely.

- And regarding this,

776

00:29:46,550 --> 00:29:49,430

you know, general idea

of working in a field,

777

00:29:49,430 --> 00:29:52,510

where you maybe don't yet have

evidence for or against it,

778

00:29:52,510 --> 00:29:54,870

it just reminds me of

something you write about

779

00:29:54,870 --> 00:29:56,610

in your book, "Seven Brief Lessons".

780

00:29:56,610 --> 00:29:58,450

When you're talking

about Einstein's theory,

781

00:29:58,450 --> 00:30:00,810

you write about how, a lot of times,

782

00:30:00,810 --> 00:30:04,310

something very important is

kind of considered useless

783

00:30:04,310 --> 00:30:05,670

at the time when it's developed.

784

00:30:05,670 --> 00:30:08,310

One example you gave

is that Rehman's work,

785

00:30:08,310 --> 00:30:11,270

that was generalizing

Gauss's explanations,

786

00:30:11,270 --> 00:30:12,880
was considered useless at the time,

787

00:30:12,880 --> 00:30:16,600
but it was then a fundamental
piece of Einstein's theory.

788

00:30:16,600 --> 00:30:18,330
So, it seems that this is very crucial,

789

00:30:18,330 --> 00:30:20,760
to work on things where
we don't actually know

790

00:30:20,760 --> 00:30:22,610
exactly what the application will be

791

00:30:22,610 --> 00:30:25,830
or exactly how long it
will be, but I'm wondering

792

00:30:25,830 --> 00:30:27,960
if you think that physicists
need to find, in general,

793

00:30:27,960 --> 00:30:30,710
some kind of a balance
between working on problems

794

00:30:30,710 --> 00:30:33,300
where we have an idea of the time horizon

795

00:30:33,300 --> 00:30:36,500
for the applications versus
working on these problems

796

00:30:36,500 --> 00:30:39,660

where we don't really
know where it will lead.

797

00:30:39,660 --> 00:30:43,690

- Yes, obviously there is a
balance to be searched there.

798

00:30:43,690 --> 00:30:47,140

If you look at this from
the main whole of Perimeter,

799

00:30:47,140 --> 00:30:49,280

as this is the same city,
hard to find balance,

800

00:30:49,280 --> 00:30:51,090

but if you look at it on a large scale,

801

00:30:51,090 --> 00:30:55,070

99.9% of the money put
into research worldwide

802

00:30:55,070 --> 00:30:57,040

is to practical applications.

803

00:30:57,040 --> 00:30:58,880

Of course, we need practical
applications, right?

804

00:30:58,880 --> 00:31:01,810

We need people who study
chemistry of materials

805

00:31:01,810 --> 00:31:04,070

because we need the certain
materials for something,

806

00:31:04,070 --> 00:31:05,970

healing people and replacing bones.

807
00:31:05,970 --> 00:31:07,220
I'm just defending.

808
00:31:07,220 --> 00:31:08,750
Applied science is great,

809
00:31:08,750 --> 00:31:12,880
but to concentrate resources
toward applied science so much,

810
00:31:12,880 --> 00:31:15,470
as is done today, I
think, it's a disaster.

811
00:31:15,470 --> 00:31:18,860
We need people who do
the kind of pure science

812
00:31:18,860 --> 00:31:21,020
or fundamental science or basic science,

813
00:31:21,020 --> 00:31:23,960
I mean, all these words
are imprecise, all of them,

814
00:31:23,960 --> 00:31:27,170
namely who don't think about application.

815
00:31:27,170 --> 00:31:29,250
Our science is built

816
00:31:29,250 --> 00:31:30,590
upon a number

817
00:31:30,590 --> 00:31:33,900
of key results obtained
through the same tests.

818

00:31:33,900 --> 00:31:35,240
If you look at each one,

819
00:31:35,240 --> 00:31:37,220
no one was looking for application,

820
00:31:37,220 --> 00:31:40,100
and if he had looked for
application at his own time,

821
00:31:40,100 --> 00:31:41,480
he wouldn't have got there.

822
00:31:41,480 --> 00:31:44,610
So, it's obvious that we need
to just ask the question,

823
00:31:44,610 --> 00:31:45,850
what's behind things?

824
00:31:45,850 --> 00:31:48,800
How can I understand better
at the fundamental level?

825
00:31:48,800 --> 00:31:51,150
Applications will come
out, sometimes fortunately,

826
00:31:51,150 --> 00:31:52,680
sometimes unfortunately

827
00:31:52,680 --> 00:31:55,810
because sometimes applications
are to kill people

828
00:31:55,810 --> 00:31:58,220
and to make war.

829
00:31:58,220 --> 00:32:00,720

- So, you're the organizer
of a research initiative

830

00:32:00,720 --> 00:32:03,790
called The Quantum Information
Structure of Spacetime,

831

00:32:03,790 --> 00:32:05,810
and this brings together theorists,

832

00:32:05,810 --> 00:32:08,240
experimentalists, and philosophers.

833

00:32:08,240 --> 00:32:10,800
Can you tell us why you
think it's so useful

834

00:32:10,800 --> 00:32:13,227
to bring together that group of people

835

00:32:13,227 --> 00:32:17,350
and what you're trying to
answer through this initiative?

836

00:32:17,350 --> 00:32:18,864
- Thank you for this question.

837

00:32:18,864 --> 00:32:21,040
The Quantum Information
Structure of Spacetime,

838

00:32:21,040 --> 00:32:24,810
the short name is QISS,
QISS, written with a Q.

839

00:32:24,810 --> 00:32:28,380
It's a big consortium with big grants,

840

00:32:28,380 --> 00:32:31,400

mostly used for supporting young people.

841

00:32:31,400 --> 00:32:32,720

A group of PI here, in fact,

842

00:32:32,720 --> 00:32:34,570

two groups of PIs are part of it,

843

00:32:34,570 --> 00:32:38,000

and there are about dozens
of group all over the world,

844

00:32:38,000 --> 00:32:40,610

from Hong Kong to Mexico, to California,

845

00:32:40,610 --> 00:32:44,550

and the aim is to bring
together two communities,

846

00:32:44,550 --> 00:32:46,170

or actually three communities.

847

00:32:46,170 --> 00:32:48,047

The two communities
are quantum information

848

00:32:48,047 --> 00:32:49,640

and quantum gravity,

849

00:32:49,640 --> 00:32:51,820

and the idea is that
quantum gravity people

850

00:32:51,820 --> 00:32:54,590

have been using quantum
information notions,

851

00:32:54,590 --> 00:32:56,770

or beginning to use it in various ways,

852

00:32:56,770 --> 00:32:59,950

and quantum information
people are starting to think

853

00:32:59,950 --> 00:33:04,260

about how quantum information
works in space and time.

854

00:33:04,260 --> 00:33:05,390

Let me say it this way,

855

00:33:05,390 --> 00:33:07,101

and so the same problems
are being addressed,

856

00:33:07,101 --> 00:33:08,710

but from a completely
different perspective.

857

00:33:08,710 --> 00:33:10,270

And the third community is philosophers

858

00:33:10,270 --> 00:33:13,610

because this dialogue opens
fundamental questions,

859

00:33:13,610 --> 00:33:15,770

like what we were saying before,

860

00:33:15,770 --> 00:33:18,350

the direction of time or the
nature of what is information,

861

00:33:18,350 --> 00:33:21,530

what we mean by information,
and in quantum gravity,

862

00:33:21,530 --> 00:33:23,950

it's a theory which is
not written in spacetime.

863

00:33:23,950 --> 00:33:26,470
So, in some sense, spacetime
has to be rethought

864

00:33:26,470 --> 00:33:28,040
to come out on the theory in some way,

865

00:33:28,040 --> 00:33:29,310
and these are philosophical questions.

866

00:33:29,310 --> 00:33:30,480
So, these are different communities

867

00:33:30,480 --> 00:33:33,890
which are being brought
together, and in June this year,

868

00:33:33,890 --> 00:33:36,650
they will be not far from
PI in London, Ontario,

869

00:33:36,650 --> 00:33:38,500
so it's just a short drive from PI,

870

00:33:38,500 --> 00:33:40,630
a conference bringing together this,

871

00:33:40,630 --> 00:33:43,490
and it's a conference
that we have organized.

872

00:33:43,490 --> 00:33:45,560
It's not a standard
conference with, you know,

873

00:33:45,560 --> 00:33:48,320

speeches and a few questions,
and, "Why do you say that?"

874

00:33:48,320 --> 00:33:51,890
Each half-day, we'll
have a few 10/15 minutes

875

00:33:51,890 --> 00:33:53,710
very short flash presentations,

876

00:33:53,710 --> 00:33:56,520
and then a couple of
hours of open discussion,

877

00:33:56,520 --> 00:33:58,720
everybody with everybody,
with a good chair,

878

00:33:58,720 --> 00:34:01,470
who sort of likes balance and follows.

879

00:34:01,470 --> 00:34:03,870
Discussion compares all points of view

880

00:34:03,870 --> 00:34:06,060
because there are these
communities, quantum information,

881

00:34:06,060 --> 00:34:09,230
quantum gravity, and philosophers
who look at these things,

882

00:34:09,230 --> 00:34:11,830
which have different ways
of viewing the same thing.

883

00:34:11,830 --> 00:34:14,890
So, we want to compare and, of course,

884

00:34:14,890 --> 00:34:16,710
learn from these differences.

885
00:34:16,710 --> 00:34:18,880
- Are there frustrations
that tend to come up

886
00:34:18,880 --> 00:34:22,220
when people with such different
backgrounds and education

887
00:34:22,220 --> 00:34:25,330
are trying to discuss a
topic with each other?

888
00:34:25,330 --> 00:34:27,500
- Yeah, there are things
you take for granted,

889
00:34:27,500 --> 00:34:29,270
then a person who's a good scientist

890
00:34:29,270 --> 00:34:30,370
comes to you and says, "You're wrong."

891
00:34:30,370 --> 00:34:32,380
You say, "Wait, (chuckles)
what do you mean I'm wrong,

892
00:34:32,380 --> 00:34:35,530
you are wrong," and that's frustrating,

893
00:34:35,530 --> 00:34:37,160
but that's great because I think

894
00:34:37,160 --> 00:34:38,627
that's how the process of knowledge works.

895
00:34:38,627 --> 00:34:40,930

You know, we learn from experiments,

896

00:34:40,930 --> 00:34:42,400

but we even more learn

897

00:34:42,400 --> 00:34:44,700

from continuous exchange of perspective,

898

00:34:44,700 --> 00:34:47,480

and the more we listen
to other perspectives,

899

00:34:47,480 --> 00:34:49,560

and that's a great opportunity, I think,

900

00:34:49,560 --> 00:34:51,530

because quantum information has boomed

901

00:34:51,530 --> 00:34:55,600

for various reasons in
the last decade, probably,

902

00:34:55,600 --> 00:34:57,470

and there are very good ideas there,

903

00:34:57,470 --> 00:34:59,480

which I think are relevant
for quantum gravity.

904

00:34:59,480 --> 00:35:01,860

On the other hand, the
people of quantum information

905

00:35:01,860 --> 00:35:03,560

are not aware that some of the things

906

00:35:03,560 --> 00:35:06,140

that they are struggling with
have already been addressed

907

00:35:06,140 --> 00:35:07,400
by quantum gravity, right?

908

00:35:07,400 --> 00:35:11,270
So, there's really a
dialogue to start here,

909

00:35:11,270 --> 00:35:13,240
and the philosopher
has an interest in both

910

00:35:13,240 --> 00:35:15,300
and have things to say about both.

911

00:35:15,300 --> 00:35:17,580
So, I hope that this dialogue in three,

912

00:35:17,580 --> 00:35:19,360
based not just in presentation,

913

00:35:19,360 --> 00:35:20,556
but in discussion, will work,

914

00:35:20,556 --> 00:35:21,750
and I look forward to that.

915

00:35:21,750 --> 00:35:23,480
- After two years of lockdown,

916

00:35:23,480 --> 00:35:26,340
of pandemics and people staying at home,

917

00:35:26,340 --> 00:35:27,900
have you felt, distinctly,

918

00:35:27,900 --> 00:35:30,770
the absence of in-person gatherings

919
00:35:30,770 --> 00:35:32,870
with other researchers and scientists,

920
00:35:32,870 --> 00:35:35,490
you know, getting together
in the same place?

921
00:35:35,490 --> 00:35:36,500
- A little bit, yes.

922
00:35:36,500 --> 00:35:38,100
For me, this has not been dramatic

923
00:35:38,100 --> 00:35:40,510
because we are all on the
internet, we're on Zoom,

924
00:35:40,510 --> 00:35:43,400
but being always on Zoom is also painful.

925
00:35:43,400 --> 00:35:46,590
This morning, finally,
it's the first day I'm back

926
00:35:46,590 --> 00:35:48,750
in PI after so long, finally!

927
00:35:48,750 --> 00:35:52,430
I was with a young colleague
in front of a blackboard,

928
00:35:52,430 --> 00:35:54,910
writing things, and I said,
"No, wait, this is not,"

929
00:35:54,910 --> 00:35:57,130
as, oh, what a pleasure. (chuckles)

930
00:35:57,130 --> 00:35:58,820
It was so long that this didn't happen.

931
00:35:58,820 --> 00:36:01,680
- And from reading the website
for this QISS initiative,

932
00:36:01,680 --> 00:36:04,190
it seems that a major goal is to deepen

933
00:36:04,190 --> 00:36:06,520
the understanding of information.

934
00:36:06,520 --> 00:36:10,320
Could you just tell us what
you think of information

935
00:36:10,320 --> 00:36:12,940
as meaning and why you
think that information

936
00:36:12,940 --> 00:36:14,620
is so fundamental?

937
00:36:14,620 --> 00:36:16,713
- Information is a very tricky
world 'cause the spectral

938
00:36:16,713 --> 00:36:19,680
of meanings is very wide, extremely wide.

939
00:36:19,680 --> 00:36:22,150
When you talk about information,
people often get confused

940
00:36:22,150 --> 00:36:24,630
because in a debate, in a dialogue,

941

00:36:24,630 --> 00:36:25,480
people mean different things,

942
00:36:25,480 --> 00:36:28,950
and it goes from the most complex one,

943
00:36:28,950 --> 00:36:31,693
I mean, do you have
information about your father?

944
00:36:32,710 --> 00:36:34,380
Of course, I know a lot about my father,

945
00:36:34,380 --> 00:36:36,820
to the most basic one,

946
00:36:36,820 --> 00:36:38,810
my little card here

947
00:36:38,810 --> 00:36:41,900
contains so many megabytes of information.

948
00:36:41,900 --> 00:36:44,390
Obviously, the two are connected somehow,

949
00:36:44,390 --> 00:36:46,620
but the two are very different,
completely different.

950
00:36:46,620 --> 00:36:49,170
About your father is something
that has to do with meaning.

951
00:36:49,170 --> 00:36:52,180
In that case, with rather
even emotions, (chuckles)

952
00:36:52,180 --> 00:36:54,350
but certainly is interpreted

information in some sense,

953

00:36:54,350 --> 00:36:58,510
so it has to do with something
that needs to be decoded,

954

00:36:58,510 --> 00:37:00,640
that has to be translated.

955

00:37:00,640 --> 00:37:04,390
In the case of the memory
card, just counting something,

956

00:37:04,390 --> 00:37:05,960
it's a number of counting something.

957

00:37:05,960 --> 00:37:07,240
It's like counting the number of atoms,

958

00:37:07,240 --> 00:37:08,770
so counting the number of something.

959

00:37:08,770 --> 00:37:10,810
In this spectrum, what is interesting

960

00:37:10,810 --> 00:37:12,320
is exactly the spectrum,

961

00:37:12,320 --> 00:37:15,150
that it has so many possible meanings,

962

00:37:15,150 --> 00:37:17,550
but what's most interesting
is the basic one,

963

00:37:17,550 --> 00:37:18,720
and the basic one,

964

00:37:18,720 --> 00:37:21,210
there's a very simple
notion of information

965
00:37:21,210 --> 00:37:24,040
which is purely physical,
which is correlation,

966
00:37:24,040 --> 00:37:26,070
when two things know about one another.

967
00:37:26,070 --> 00:37:28,037
If you glue two things, if
one points in one direction,

968
00:37:28,037 --> 00:37:30,164
the other also points in that direction.

969
00:37:30,164 --> 00:37:31,640
If you know one, you know the other one.

970
00:37:31,640 --> 00:37:33,180
So, one has information about that,

971
00:37:33,180 --> 00:37:35,070
meaning that there is a
correlation between the two.

972
00:37:35,070 --> 00:37:35,993
That's the basic notion of information,

973
00:37:35,993 --> 00:37:38,140
it's purely physical, nothing mental,

974
00:37:38,140 --> 00:37:39,730
no meaning, no significance.

975
00:37:39,730 --> 00:37:41,030
That's the basic notion of information,

976

00:37:41,030 --> 00:37:43,560

and I think this notion of
information is fundamental,

977

00:37:43,560 --> 00:37:45,347

not because the world
is made by information,

978

00:37:45,347 --> 00:37:47,070

the world is made by stuff,

979

00:37:47,070 --> 00:37:48,890

by variables, by things which are,

980

00:37:48,890 --> 00:37:52,710

but because the world
is made by relations,

981

00:37:52,710 --> 00:37:55,500

the properties of things are
relative to something else.

982

00:37:55,500 --> 00:37:57,067

So, if you want to describe
the structure of the world,

983

00:37:57,067 --> 00:37:59,360

you're always talking about how one thing

984

00:37:59,360 --> 00:38:00,330

affects another one,

985

00:38:00,330 --> 00:38:02,290

so how they get correlated
to the other one.

986

00:38:02,290 --> 00:38:05,120

So, immediately, you can quantify

987

00:38:05,120 --> 00:38:07,180
how much things affect one another

988

00:38:07,180 --> 00:38:09,780
by using the notion of
information, and this means,

989

00:38:09,780 --> 00:38:11,840
not information as an
ingredient of the world,

990

00:38:11,840 --> 00:38:14,600
but as a key ingredient of
our thinking about the world.

991

00:38:14,600 --> 00:38:16,240
I think quantum mechanics itself

992

00:38:16,240 --> 00:38:18,380
can be largely thought of in this way.

993

00:38:18,380 --> 00:38:20,470
I've been thinking this
since back in the '90s,

994

00:38:20,470 --> 00:38:21,930
when I started thinking about the notion

995

00:38:21,930 --> 00:38:24,040
of quantum mechanics, and because of that,

996

00:38:24,040 --> 00:38:25,400
I think, in quantum gravity,

997

00:38:25,400 --> 00:38:27,740
it also could be a
fundamental role to thinking

998

00:38:27,740 --> 00:38:30,110
about information systems
helping out one another,

999

00:38:30,110 --> 00:38:33,820
but once we go into this way
of thinking about physics,

1000

00:38:33,820 --> 00:38:35,550
not as how systems are,

1001

00:38:35,550 --> 00:38:37,700
but how systems have
information about all of that,

1002

00:38:37,700 --> 00:38:39,490
how they're correlated, then it's easier

1003

00:38:39,490 --> 00:38:41,640
to understand that there's a continuity

1004

00:38:41,640 --> 00:38:43,980
to the most complicated
notion of information.

1005

00:38:43,980 --> 00:38:48,500
So, the mental is not so far
away from the physical now

1006

00:38:48,500 --> 00:38:50,440
'cause we start taking the physical

1007

00:38:50,440 --> 00:38:51,770
from the right perspective,

1008

00:38:51,770 --> 00:38:53,670
from which it's easier to reconstruct

1009

00:38:53,670 --> 00:38:56,020
the more complicated
notion of information,

1010
00:38:56,020 --> 00:38:58,800
meaning, for instance, we
talk about memory traces,

1011
00:38:58,800 --> 00:39:01,090
and we build it up more
and more complicated.

1012
00:39:01,090 --> 00:39:04,350
So, it's a very versatile,
rich, confusing,

1013
00:39:04,350 --> 00:39:07,760
but key notion for understanding
the world information

1014
00:39:07,760 --> 00:39:11,430
because the world is made
by relations, not by things.

1015
00:39:11,430 --> 00:39:13,280
- In reality, it's not what it seems.

1016
00:39:13,280 --> 00:39:14,113
There's a passage that I love,

1017
00:39:14,113 --> 00:39:15,930
and I even told you
about it after I read it,

1018
00:39:15,930 --> 00:39:17,630
because you go through so much of the book

1019
00:39:17,630 --> 00:39:21,260
explaining the historical
context of quantum gravity

1020

00:39:21,260 --> 00:39:24,190

and explaining the concepts
in very easy-to-follow terms,

1021

00:39:24,190 --> 00:39:26,350

which I appreciate, and
then later in the book,

1022

00:39:26,350 --> 00:39:29,170

you say, "If, dear reader,
you have found the journey

1023

00:39:29,170 --> 00:39:31,550

so far a little rough, hold on tighter

1024

00:39:31,550 --> 00:39:34,390

because we're now flying
between voids of air."

1025

00:39:34,390 --> 00:39:36,957

And then you get into your
new ideas, which you said,

1026

00:39:36,957 --> 00:39:39,090

"If the ideas seem confused,

1027

00:39:39,090 --> 00:39:41,640

it's because the person with
the confused mind is me."

1028

00:39:41,640 --> 00:39:44,890

First of all, that's
something I don't often see

1029

00:39:44,890 --> 00:39:48,010

in popular science books, is
the warning to the reader,

1030

00:39:48,010 --> 00:39:50,870
like, it's okay to be shaken by this,

1031
00:39:50,870 --> 00:39:52,520
it's okay to not fully get it.

1032
00:39:52,520 --> 00:39:55,290
So, you gave this warning,
and then you expressed ideas

1033
00:39:55,290 --> 00:39:58,570
that you personally don't
have a full concept of.

1034
00:39:58,570 --> 00:40:00,870
Can you explain a little
bit about what that's like,

1035
00:40:00,870 --> 00:40:04,200
going into territory that
is less historically sound

1036
00:40:04,200 --> 00:40:06,540
and more speculative, and
putting your own ideas out

1037
00:40:06,540 --> 00:40:07,640
on the line like that?

1038
00:40:08,800 --> 00:40:11,371
- There is a lot about
the world we understand,

1039
00:40:11,371 --> 00:40:13,320
and there's a lot we don't understand.

1040
00:40:13,320 --> 00:40:15,670
It doesn't make much sense

1041

00:40:15,670 --> 00:40:17,630
what we too often do, in my opinion,

1042
00:40:17,630 --> 00:40:19,510
which is to pretend that we understand

1043
00:40:19,510 --> 00:40:21,780
the part we don't understand.

1044
00:40:21,780 --> 00:40:24,480
University professors that
teach and lecture on physics,

1045
00:40:24,480 --> 00:40:26,270
they shouldn't pretend that
they know everything about it.

1046
00:40:26,270 --> 00:40:28,910
They don't know about it,
and they may be wrong.

1047
00:40:28,910 --> 00:40:30,760
I mean, they might be teaching
things which are wrong,

1048
00:40:30,760 --> 00:40:32,803
so they should say, look,
this is what we understand,

1049
00:40:32,803 --> 00:40:34,760
this is what I understand,

1050
00:40:34,760 --> 00:40:37,171
and be aware that there
might be something wrong,

1051
00:40:37,171 --> 00:40:38,750
and if there's something confusing,

1052

00:40:38,750 --> 00:40:41,030
it might well be because it is confusing

1053
00:40:41,030 --> 00:40:43,200
or because a person is confused

1054
00:40:43,200 --> 00:40:44,900
or because the community is confused.

1055
00:40:44,900 --> 00:40:46,370
A good example is quantum mechanics.

1056
00:40:46,370 --> 00:40:49,320
Quantum mechanics is a hundred years old,

1057
00:40:49,320 --> 00:40:50,810
spectacularly successful,

1058
00:40:50,810 --> 00:40:53,220
used in technological
applications everywhere,

1059
00:40:53,220 --> 00:40:54,850
but it's still confusing,

1060
00:40:54,850 --> 00:40:56,840
and the fact it's confusing may be good

1061
00:40:56,840 --> 00:40:59,830
because it may be that we
still haven't got something,

1062
00:40:59,830 --> 00:41:01,630
some right way of looking at it,

1063
00:41:01,630 --> 00:41:03,450
so let's say it's confusing.

1064

00:41:03,450 --> 00:41:06,190
I think this makes, also, things easier

1065
00:41:06,190 --> 00:41:09,540
for the student at university
or for the reader of a book

1066
00:41:09,540 --> 00:41:13,509
who is not presented this, you know,

1067
00:41:13,509 --> 00:41:18,130
both white, clean piece of stone
saying, this is it, period.

1068
00:41:18,130 --> 00:41:19,340
We are humans.

1069
00:41:19,340 --> 00:41:21,710
Science is a human activity,
like everything else.

1070
00:41:21,710 --> 00:41:24,606
It's dirty, it's
imprecise, there are holes,

1071
00:41:24,606 --> 00:41:27,210
so I think it's better
to present what it is.

1072
00:41:27,210 --> 00:41:29,260
- I connected with the
idea that you yourself

1073
00:41:29,260 --> 00:41:30,867
are struggling with these ideas,

1074
00:41:30,867 --> 00:41:33,410
and when you read a book by
an expert on any subject,

1075
00:41:33,410 --> 00:41:35,700
you assume the expert knows everything,

1076
00:41:35,700 --> 00:41:37,250
and for you to say later
in the book, you know,

1077
00:41:37,250 --> 00:41:39,500
here's what I'm grappling with, it helps.

1078
00:41:39,500 --> 00:41:40,960
I think it helps the reader understand

1079
00:41:40,960 --> 00:41:42,120
that this is a difficult,

1080
00:41:42,120 --> 00:41:44,020
complex pursuit.
- Yeah, my book,

1081
00:41:44,020 --> 00:41:46,860
my books are a little
bit different in spirit

1082
00:41:46,860 --> 00:41:50,860
from most popular science books
because they also are aimed

1083
00:41:50,860 --> 00:41:53,930
at a slightly different
audience, and in fact,

1084
00:41:53,930 --> 00:41:57,910
I've remarked, from the
reactions that I get,

1085
00:41:57,910 --> 00:42:01,830
that the typical reader of science books

1086
00:42:01,830 --> 00:42:05,790
likes my books less, and
the people who like my book

1087
00:42:05,790 --> 00:42:07,420
are a little on the extreme sides,

1088
00:42:07,420 --> 00:42:10,460
are either people who
know zero about science

1089
00:42:10,460 --> 00:42:12,400
or people who know a lot about science.

1090
00:42:12,400 --> 00:42:14,660
And I understand the
reason because I think,

1091
00:42:14,660 --> 00:42:16,150
at these two extreme categories,

1092
00:42:16,150 --> 00:42:19,000
when I'm talking about them,
the typical science book,

1093
00:42:19,000 --> 00:42:21,630
it's written for somebody who
wants to know more and more

1094
00:42:21,630 --> 00:42:23,750
and more and more and
more about some domain,

1095
00:42:23,750 --> 00:42:25,587
so you give more details,
you give more information.

1096
00:42:25,587 --> 00:42:27,550
You say, "Oh, and we know

that, and we know that,

1097

00:42:27,550 --> 00:42:30,390
and we know that," and
you know, there are kids,

1098

00:42:30,390 --> 00:42:32,290
nerds that really want to
know more and more and more

1099

00:42:32,290 --> 00:42:35,290
about the neutrinos and all the
possible details about that.

1100

00:42:35,290 --> 00:42:36,890
I don't do that, I do the opposite.

1101

00:42:36,890 --> 00:42:38,980
I take away, I take away, I take away.

1102

00:42:38,980 --> 00:42:41,240
I strip away as much as possible,

1103

00:42:41,240 --> 00:42:44,800
trying to reduce to what
seems to be the core

1104

00:42:44,800 --> 00:42:47,470
that we have understood about something

1105

00:42:47,470 --> 00:42:50,210
and to present it in a way
that it stays together,

1106

00:42:50,210 --> 00:42:53,757
it holds on, and allows the
reader to understand what it is

1107

00:42:53,757 --> 00:42:57,000

and what seems to me the real
thing we have understood.

1108
00:42:57,000 --> 00:42:58,110
And then, of course,

1109
00:42:58,110 --> 00:43:00,060
those who know nothing
about science, they like it,

1110
00:43:00,060 --> 00:43:01,890
because they say, "Oh,
great, I get to that, yeah,"

1111
00:43:01,890 --> 00:43:04,820
and those who know a lot
about science also like it,

1112
00:43:04,820 --> 00:43:06,410
because they say, "Oh,
wow, that's a good way

1113
00:43:06,410 --> 00:43:08,220
of doing things, maybe
I didn't think this way,

1114
00:43:08,220 --> 00:43:09,410
maybe I was thinking the other way.

1115
00:43:09,410 --> 00:43:11,910
That's a new perspective on things."

1116
00:43:11,910 --> 00:43:14,047
And a lot of my best colleagues tell me,

1117
00:43:14,047 --> 00:43:16,310
"Ah, I have read your book, wow!

1118
00:43:16,310 --> 00:43:18,140

I didn't think about
this way of putting it.

1119
00:43:18,140 --> 00:43:20,070
Great, great, I learned something."

1120
00:43:20,070 --> 00:43:23,150
Even my greatest enemy, the
chief of the opposite, you know,

1121
00:43:23,150 --> 00:43:26,690
band theoretical physics,
who is a Nobel Prize winner,

1122
00:43:26,690 --> 00:43:29,720
sent a message to me and
said, "Fantastic, I loved it."

1123
00:43:29,720 --> 00:43:31,560
But the students of physics,

1124
00:43:31,560 --> 00:43:34,350
who've just studied that at school,

1125
00:43:34,350 --> 00:43:35,980
reads what I'm saying and knows,

1126
00:43:35,980 --> 00:43:37,350
because they say, "Wait a minute, I mean,

1127
00:43:37,350 --> 00:43:38,580
there's all missing here."

1128
00:43:38,580 --> 00:43:40,437
I got an email saying,

1129
00:43:40,437 --> 00:43:44,330
"You talk about quantum
mechanics in the seven lessons.

1130

00:43:44,330 --> 00:43:46,420

You don't even mention
the Schrödinger equation."

1131

00:43:46,420 --> 00:43:47,396

I thought, yeah, that's right,

1132

00:43:47,396 --> 00:43:48,881

I don't mention the Schrödinger equation,

1133

00:43:48,881 --> 00:43:50,480

but that's not the core.

- The right story.

1134

00:43:50,480 --> 00:43:53,340

- Right, so yes, and this
connects to your question,

1135

00:43:53,340 --> 00:43:55,900

what you were saying
before, because to do that,

1136

00:43:55,900 --> 00:43:58,640

you need to understand
something all the way through.

1137

00:43:58,640 --> 00:44:02,020

So, once we have totally
digested something,

1138

00:44:02,020 --> 00:44:04,930

then you can just, bingo,
you know, in one phrase.

1139

00:44:04,930 --> 00:44:06,490

- You can whittle it down to the essence.

1140

00:44:06,490 --> 00:44:07,790

- To the essence, right?
- Yeah.

1141
00:44:07,790 --> 00:44:09,207
- I mean, take Copernicus.

1142
00:44:09,207 --> 00:44:11,480
If you read the book of Copernicus,

1143
00:44:11,480 --> 00:44:16,400
300 pages of calculations,
detail, geometry, perspective.

1144
00:44:16,400 --> 00:44:18,987
It's horrendously
complicated, then the equant,

1145
00:44:18,987 --> 00:44:21,697
the epicycles still, and
then this and this and that,

1146
00:44:21,697 --> 00:44:25,100
and to make this complicated,
and the moon is complicated.

1147
00:44:25,100 --> 00:44:27,960
What is it, 400 years
have gone from Copernicus?

1148
00:44:27,960 --> 00:44:30,410
Now we have digested everything,
can say it in two lines,

1149
00:44:30,410 --> 00:44:31,917
the earth is spinning

1150
00:44:31,917 --> 00:44:33,760
and is orbiting around the sun.

1151

00:44:33,760 --> 00:44:36,950
That's what Copernicus has
qualified, so it's totally clear.

1152
00:44:36,950 --> 00:44:39,540
It's strange if you think
about we are actually moving.

1153
00:44:39,540 --> 00:44:41,020
It's revolutionary.

1154
00:44:41,020 --> 00:44:42,127
It changes everything.

1155
00:44:42,127 --> 00:44:43,960
The earth isn't violent, like the others,

1156
00:44:43,960 --> 00:44:45,820
but it can be said in two lines.

1157
00:44:45,820 --> 00:44:48,080
Once we have really understood something,

1158
00:44:48,080 --> 00:44:49,650
at the end, we can say it in two lines

1159
00:44:49,650 --> 00:44:52,610
in a way that has it, has it really,

1160
00:44:52,610 --> 00:44:54,140
and the people understand what it is.

1161
00:44:54,140 --> 00:44:56,640
So, my ambition, but we're not there,

1162
00:44:56,640 --> 00:44:59,450
would be to do the same I
just did with Copernicus,

1163

00:44:59,450 --> 00:45:01,390

the same with, you know,
the standard models,

1164

00:45:01,390 --> 00:45:03,990

special relativity, general
relativity, quantum mechanics,

1165

00:45:03,990 --> 00:45:05,820

quantum field theory, quantum gravity.

1166

00:45:05,820 --> 00:45:08,007

- You said in one piece you wrote,

1167

00:45:08,007 --> 00:45:09,750

"Sometimes dreams come true.

1168

00:45:09,750 --> 00:45:11,820

I felt there was a story
about the adventure

1169

00:45:11,820 --> 00:45:13,440

of physics that had to be told,

1170

00:45:13,440 --> 00:45:15,420

but I thought people were not interested,"

1171

00:45:15,420 --> 00:45:16,410

but you were wrong.

1172

00:45:16,410 --> 00:45:18,610

You were dead wrong because a
lot of people were interested.

1173

00:45:18,610 --> 00:45:20,450

You know, millions of
people have read your book.

1174

00:45:20,450 --> 00:45:22,890
It's translated into dozens of languages.

1175
00:45:22,890 --> 00:45:23,900
What do you think you got wrong

1176
00:45:23,900 --> 00:45:26,542
about estimating people's
interest in this subject matter?

1177
00:45:26,542 --> 00:45:29,480
- (laughs) It was not just me wrong,

1178
00:45:29,480 --> 00:45:31,870
the "Seven Brief Lessons on Physics"

1179
00:45:31,870 --> 00:45:35,000
was printed in about 5,000 copies.

1180
00:45:35,000 --> 00:45:37,360
That was the estimate of the publisher

1181
00:45:37,360 --> 00:45:39,020
that was going to sell.
- Yeah.

1182
00:45:39,020 --> 00:45:40,930
Do you think it was
because you whittled down

1183
00:45:40,930 --> 00:45:43,110
to the essence and you
left out the equations?

1184
00:45:43,110 --> 00:45:45,010
- No, I think it's because,

1185
00:45:45,010 --> 00:45:47,830
mostly because of the last

chapter of the seventh.

1186

00:45:47,830 --> 00:45:49,980

I think that's what made the book.

1187

00:45:49,980 --> 00:45:52,550

It's a book that is
not just about physics,

1188

00:45:52,550 --> 00:45:55,590

it's a book that tries
to go down to the essence

1189

00:45:55,590 --> 00:45:57,580

and then asks the question, all right,

1190

00:45:57,580 --> 00:45:59,100

so what does it mean for us?

1191

00:45:59,100 --> 00:46:02,730

How does it reflect on
the way we see ourself

1192

00:46:02,730 --> 00:46:06,010

and the way we think about the
material, the physical world,

1193

00:46:06,010 --> 00:46:08,370

and our, let me use a strong
word, spiritual world.

1194

00:46:08,370 --> 00:46:11,270

Let me tell you my interpretation of that.

1195

00:46:11,270 --> 00:46:14,400

I and my friends, and
many people around me,

1196

00:46:14,400 --> 00:46:18,300

share a view of the world
which is not much known

1197
00:46:18,300 --> 00:46:21,290
by a large majority of the population,

1198
00:46:21,290 --> 00:46:25,280
and it's a view of the
world that is neither

1199
00:46:25,280 --> 00:46:27,060
the world is made by little atoms

1200
00:46:27,060 --> 00:46:29,770
bouncing with one another and that's it,

1201
00:46:29,770 --> 00:46:32,060
emotions, the sense of lives, whatever,

1202
00:46:32,060 --> 00:46:34,230
that's bullshit that comes later.

1203
00:46:34,230 --> 00:46:36,310
It's neither that, but it's neither

1204
00:46:37,200 --> 00:46:39,010
the material world is irrelevant,

1205
00:46:39,010 --> 00:46:43,580
there is a spiritual world,
with God, morality and things,

1206
00:46:43,580 --> 00:46:45,930
that's what the reality is.

1207
00:46:45,930 --> 00:46:48,710
Somehow, a lot of people
are unhappy with both

1208
00:46:48,710 --> 00:46:51,600
because they don't believe
the spiritual world

1209
00:46:51,600 --> 00:46:54,110
too much anymore because
we're in a secular society,

1210
00:46:54,110 --> 00:46:56,890
which doesn't hold anymore
for a large number of people,

1211
00:46:56,890 --> 00:46:59,650
but neither people find convincing,

1212
00:46:59,650 --> 00:47:02,620
a sort of cold and ground cynicism,

1213
00:47:02,620 --> 00:47:06,120
which has no hold for
meaning, for emotion,

1214
00:47:06,120 --> 00:47:08,830
for our aim, for what we are thinking

1215
00:47:08,830 --> 00:47:10,600
and desiring and suffering.

1216
00:47:10,600 --> 00:47:13,763
So, the fact that somehow
people find in my book

1217
00:47:13,763 --> 00:47:15,520
a perspective where the two things

1218
00:47:15,520 --> 00:47:16,850
can very well stay together,

1219

00:47:16,850 --> 00:47:18,790
and there's no contradiction
between one another,

1220
00:47:18,790 --> 00:47:22,527
is when a lot of people jump in and say,

1221
00:47:22,527 --> 00:47:24,890
"Oh," but then there
are people who can think

1222
00:47:24,890 --> 00:47:27,360
that what matters for me is my emotions,

1223
00:47:27,360 --> 00:47:29,390
but also, there's nothing in contradiction

1224
00:47:29,390 --> 00:47:30,880
with fundamental science there.

1225
00:47:30,880 --> 00:47:32,490
I think that this is the bringing together

1226
00:47:32,490 --> 00:47:33,860
that made people react.

1227
00:47:33,860 --> 00:47:37,060
- And regarding this goal
that you have in your writing

1228
00:47:37,060 --> 00:47:40,140
of getting to the essence of a concept,

1229
00:47:40,140 --> 00:47:42,110
I would think this would
be uniquely challenging

1230
00:47:42,110 --> 00:47:44,100
when you're talking

about something like time

1231

00:47:44,100 --> 00:47:47,940
because the average person
will probably talk about time

1232

00:47:47,940 --> 00:47:49,480
at least once in a typical day.

1233

00:47:49,480 --> 00:47:51,890
So, there must be a lot
that you need to strip away

1234

00:47:51,890 --> 00:47:54,390
because the average person
has a lot of assumptions

1235

00:47:54,390 --> 00:47:56,970
that they're making about this word, time.

1236

00:47:56,970 --> 00:47:59,630
Can you tell us about
what that process was like

1237

00:47:59,630 --> 00:48:01,630
when you're describing time?

1238

00:48:01,630 --> 00:48:05,300
- I wrote a book just
uniquely, entirely about time,

1239

00:48:05,300 --> 00:48:07,450
and that was not an easy-to-write book

1240

00:48:07,450 --> 00:48:10,760
because exactly for the
reason you're asking.

1241

00:48:10,760 --> 00:48:12,390

When I decided how to write this book,

1242

00:48:12,390 --> 00:48:14,443

I exactly asked myself this question.

1243

00:48:15,460 --> 00:48:18,500

And so, the first half, the
longest half of the book,

1244

00:48:18,500 --> 00:48:21,500

one chapter after chapter
demolishing something

1245

00:48:21,500 --> 00:48:23,370

we take for granted, our time,

1246

00:48:23,370 --> 00:48:25,600

and on good grounds, on things we know.

1247

00:48:25,600 --> 00:48:28,020

So, we think that time has
this property, and you know,

1248

00:48:28,020 --> 00:48:30,150

it seems obvious to be that,
that's the way we think,

1249

00:48:30,150 --> 00:48:32,550

and now I tell you it's not the case,

1250

00:48:32,550 --> 00:48:34,730

and I show why we know it's not the case.

1251

00:48:34,730 --> 00:48:37,392

So, the first part of the book, in part,

1252

00:48:37,392 --> 00:48:40,320

it's just a way of telling
Boltzmann's theory,

1253
00:48:40,320 --> 00:48:42,480
of telling Einstein's special relativity,

1254
00:48:42,480 --> 00:48:45,310
putting the various pieces
of the story together,

1255
00:48:45,310 --> 00:48:47,120
but not just for talking about physics,

1256
00:48:47,120 --> 00:48:49,060
for talking, look, what this implies

1257
00:48:49,060 --> 00:48:50,940
with respect to our notion of time.

1258
00:48:50,940 --> 00:48:54,270
Special relativity definitely
changes our notion of time.

1259
00:48:54,270 --> 00:48:57,400
Notion of present everywhere
in the universe doesn't hold,

1260
00:48:57,400 --> 00:48:59,190
but it's hard to think of
the world without a notion

1261
00:48:59,190 --> 00:49:00,940
of present everywhere in the universe.

1262
00:49:00,940 --> 00:49:03,560
The question, what is going
on right now on Andromeda,

1263
00:49:03,560 --> 00:49:05,580
the galaxy, is meaningless.

1264
00:49:05,580 --> 00:49:07,940
There's no meaning, what
is going on right now.

1265
00:49:07,940 --> 00:49:09,850
There's no now in Andromeda.

1266
00:49:09,850 --> 00:49:12,990
It's like asking, what is
going on here in Beijing?

1267
00:49:12,990 --> 00:49:14,800
We're not in Beijing, so
it's not here in Beijing,

1268
00:49:14,800 --> 00:49:16,010
Beijing is elsewhere.

1269
00:49:16,010 --> 00:49:18,960
The book was designed exactly

1270
00:49:18,960 --> 00:49:20,930
to address what you are saying,

1271
00:49:20,930 --> 00:49:24,770
to take away, one by one,
the suppositions of people

1272
00:49:24,770 --> 00:49:27,830
that the people give
for granted in science.

1273
00:49:27,830 --> 00:49:30,503
Some of my colleagues
which are very reflective,

1274
00:49:30,503 --> 00:49:32,590
a written book, there's
absolutely nothing they learn

1275
00:49:32,590 --> 00:49:35,220
because they have gone through that,

1276
00:49:35,220 --> 00:49:36,770
but there are a lot of my colleagues

1277
00:49:36,770 --> 00:49:39,270
that teach special relativity
and never have stopped

1278
00:49:39,270 --> 00:49:41,140
in thinking what,
actually, they're teaching,

1279
00:49:41,140 --> 00:49:42,350
and I think that's wrong.

1280
00:49:42,350 --> 00:49:45,390
I mean, physics is interesting
because it tells us something

1281
00:49:45,390 --> 00:49:48,480
about the world, not just
because you write equations,

1282
00:49:48,480 --> 00:49:49,910
and then you make a prediction

1283
00:49:49,910 --> 00:49:51,520
and it matches with what you measured.

1284
00:49:51,520 --> 00:49:53,283
- Are you yet at a
stage where you can give

1285
00:49:53,283 --> 00:49:56,370
just this one or two sentence definitions

1286
00:49:56,370 --> 00:49:58,523
that's the core of what time is?

1287
00:49:59,450 --> 00:50:02,370
- No, with time, it's
very complicated, (laughs)

1288
00:50:02,370 --> 00:50:04,720
and the reason is because
we haven't got to the end

1289
00:50:04,720 --> 00:50:06,350
of understanding it.

1290
00:50:06,350 --> 00:50:07,930
There are things about time

1291
00:50:07,930 --> 00:50:09,610
which I think were generally confused.

1292
00:50:09,610 --> 00:50:12,550
A lot of things we have
figured out with total clarity,

1293
00:50:12,550 --> 00:50:14,440
like the nonexistence of a present

1294
00:50:14,440 --> 00:50:15,650
everywhere in the universe,

1295
00:50:15,650 --> 00:50:18,180
but there are issues about
how to think about time

1296
00:50:18,180 --> 00:50:20,240
in a wholly consistent way
with everything we know,

1297

00:50:20,240 --> 00:50:21,850
which I don't think we'll figure out.

1298
00:50:21,850 --> 00:50:24,730
Even the direction of time is implicated

1299
00:50:24,730 --> 00:50:26,830
because we have connected it to entropy,

1300
00:50:26,830 --> 00:50:28,390
to the microscopic description,

1301
00:50:28,390 --> 00:50:29,783
but there are definitely holes

1302
00:50:29,783 --> 00:50:31,800
in our understanding, in my opinion.

1303
00:50:31,800 --> 00:50:33,530
- I found that book, "The Order of Time",

1304
00:50:33,530 --> 00:50:37,480
to really make my brain meld
and squish in other directions.

1305
00:50:37,480 --> 00:50:39,970
I was listening to the audio
book, and at one point,

1306
00:50:39,970 --> 00:50:44,030
I was rushing somewhere, and
something you wrote about time

1307
00:50:44,030 --> 00:50:45,930
made me think, why am I rushing anywhere,

1308
00:50:45,930 --> 00:50:48,280
a rush is an illusion.
(Carlo laughing)

1309

00:50:48,280 --> 00:50:50,450

So, I appreciated your
writing of that book.

1310

00:50:50,450 --> 00:50:53,610

I also really liked Benedict
Cumberbatch reading it to me.

1311

00:50:53,610 --> 00:50:56,150

That was a nice experience.

1312

00:50:56,150 --> 00:50:59,161

Boy, it helps when these concepts are-

1313

00:50:59,161 --> 00:51:00,643

- He's astonishingly good.

- Are so mind-bending.

1314

00:51:00,643 --> 00:51:01,960

- Yeah, he's really good.

- Yes, yes,

1315

00:51:01,960 --> 00:51:04,487

I've been listening to

his voice and saying,

1316

00:51:04,487 --> 00:51:05,987

"Wow, who wrote these wonderful things,"

1317

00:51:05,987 --> 00:51:09,150

because it's too good for,

it's certainly not me.

1318

00:51:09,150 --> 00:51:11,660

He has a way of making it a principle,

1319

00:51:11,660 --> 00:51:13,990

but also, it's like it's talking to you

1320
00:51:13,990 --> 00:51:16,324
and telling you like a friend-

1321
00:51:16,324 --> 00:51:18,980
- Yeah, but we actually have
another student question

1322
00:51:18,980 --> 00:51:20,550
about your books.
- Yeah.

1323
00:51:20,550 --> 00:51:23,080
This question was sent in by a PhD student

1324
00:51:23,080 --> 00:51:24,400
here at Perimeter.

1325
00:51:24,400 --> 00:51:27,780
- This is Mac Du Shen, a
student at IQC in Perimeter,

1326
00:51:27,780 --> 00:51:29,060
writing, how did you first get started

1327
00:51:29,060 --> 00:51:30,408
into writing science books,

1328
00:51:30,408 --> 00:51:32,850
and how has that writing
helped your own research?

1329
00:51:32,850 --> 00:51:34,340
Do you find writing a technical paper

1330
00:51:34,340 --> 00:51:36,513
or a more accessible
book more challenging?

1331
00:51:37,950 --> 00:51:41,000
- Probably a book for a general audience.

1332
00:51:41,000 --> 00:51:42,970
You write a paper, a scientific paper,

1333
00:51:42,970 --> 00:51:44,810
after you've figured something out.

1334
00:51:44,810 --> 00:51:47,060
So, you just get confused in a problem,

1335
00:51:47,060 --> 00:51:51,040
and either alone or with some
somebody else in physics,

1336
00:51:51,040 --> 00:51:53,110
we worked mostly in little groups,

1337
00:51:53,110 --> 00:51:55,940
two or three in theoretical
physics, you sort of come out,

1338
00:51:55,940 --> 00:51:57,580
and at some point, it's clear,

1339
00:51:57,580 --> 00:51:58,770
and then you write it down,

1340
00:51:58,770 --> 00:52:00,590
and you write down what you've understood.

1341
00:52:00,590 --> 00:52:02,680
So, the writing is relatively easy.

1342
00:52:02,680 --> 00:52:05,580
I'm picky, I'm complicated in
writing scientific articles.

1343

00:52:05,580 --> 00:52:07,810

I try to write them clear,

1344

00:52:07,810 --> 00:52:10,310

so I spend time writing and
rewriting and rewriting,

1345

00:52:10,310 --> 00:52:13,180

perhaps more than what I should or could.

1346

00:52:13,180 --> 00:52:16,220

But the writing is, you know
what you're saying exactly,

1347

00:52:16,220 --> 00:52:17,950

while when you're writing a book,

1348

00:52:17,950 --> 00:52:19,660

you still don't know what you're saying.

1349

00:52:19,660 --> 00:52:23,270

You're picking up what you're
saying in the writing itself,

1350

00:52:23,270 --> 00:52:25,600

and writing, for me, is
a complicated process.

1351

00:52:25,600 --> 00:52:29,050

My books are the result of
a large number of revisions

1352

00:52:29,050 --> 00:52:31,280

and a large number of cancellations,

1353

00:52:31,280 --> 00:52:33,960

because I say, no, this is
not useful for what comes,

1354

00:52:33,960 --> 00:52:35,590
and that's just superfluous.

1355

00:52:35,590 --> 00:52:39,067
So, the same phrase, I
rewrite it 10 times and say,

1356

00:52:39,067 --> 00:52:40,480
"No, that's not clear, I mean,

1357

00:52:40,480 --> 00:52:42,070
is there a way to say it better?"

1358

00:52:42,070 --> 00:52:43,930
That's the heart of writing for me.

1359

00:52:43,930 --> 00:52:45,090
- I was just gonna say, for you,

1360

00:52:45,090 --> 00:52:47,610
it seems that this must be
particularly challenging

1361

00:52:47,610 --> 00:52:48,900
because you're not just writing

1362

00:52:48,900 --> 00:52:50,280
a book for the general public.

1363

00:52:50,280 --> 00:52:52,690
As you said, you're hoping that your book

1364

00:52:52,690 --> 00:52:54,730
will be influential
for the general public,

1365

00:52:54,730 --> 00:52:57,060

and also for experts in the field,

1366

00:52:57,060 --> 00:52:59,610
even though the material is not technical

1367

00:52:59,610 --> 00:53:01,350
or maybe doesn't rely on math.

1368

00:53:01,350 --> 00:53:05,080
So, I would assume writing
something that can be a good fit

1369

00:53:05,080 --> 00:53:08,070
for both of those audiences
must be very challenging.

1370

00:53:08,070 --> 00:53:11,090
- Yes, it is, and I have
these two readers in mind,

1371

00:53:11,090 --> 00:53:13,450
the super expert one who knows everything,

1372

00:53:13,450 --> 00:53:15,440
and the one who knows nothing,

1373

00:53:15,440 --> 00:53:19,060
which is good because thinking
like the super expert one

1374

00:53:19,060 --> 00:53:21,930
is what, you know, warns me
from not saying something,

1375

00:53:21,930 --> 00:53:25,247
which is, oh, if I say that,
he's gonna complain, (chuckles)

1376

00:53:25,247 --> 00:53:28,050

and thinking about the typical grandmother

1377

00:53:28,050 --> 00:53:29,573

who doesn't know anything
stops me from saying things,

1378

00:53:29,573 --> 00:53:31,270

oh, but that's too complicated, I mean,

1379

00:53:31,270 --> 00:53:32,950

how can anybody get this point?

1380

00:53:32,950 --> 00:53:34,640

So, I always have these struggles,

1381

00:53:34,640 --> 00:53:37,670

so this simplifies because
it gives me guidance,

1382

00:53:37,670 --> 00:53:39,780

but yes, it's also a complication to try

1383

00:53:39,780 --> 00:53:42,660

because I'm putting my
own ideas in the books,

1384

00:53:42,660 --> 00:53:45,210

mostly because it's my
own perspective of things,

1385

00:53:45,210 --> 00:53:47,450

writing a book of quantum mechanics,

1386

00:53:47,450 --> 00:53:49,030

which is entirely from the perspectives

1387

00:53:49,030 --> 00:53:51,700

of Heisenberg, Born, Dirac,

1388

00:53:51,700 --> 00:53:54,790
rather than from the
perspective of Schrödinger.

1389

00:53:54,790 --> 00:53:56,823
So, it's taken quantum
mechanics because I think

1390

00:53:56,823 --> 00:53:58,440
it's the most interesting thing.

1391

00:53:58,440 --> 00:53:59,840
I'm not the only one, but there are people

1392

00:53:59,840 --> 00:54:01,571
who think different, who
think, no, no, no, no,

1393

00:54:01,571 --> 00:54:03,090
quantum mechanics is all
about the Schrödinger equation

1394

00:54:03,090 --> 00:54:06,400
and the wave function
evolving, that's all there is.

1395

00:54:06,400 --> 00:54:07,440
I think that's wrong.

1396

00:54:07,440 --> 00:54:10,880
My books are a way of
defending a perspective,

1397

00:54:10,880 --> 00:54:12,600
but the two things help one another

1398

00:54:12,600 --> 00:54:14,373
because in the moment in which you try

1399
00:54:14,373 --> 00:54:18,560
to explain something simple,
you get clarity yourself.

1400
00:54:18,560 --> 00:54:21,020
I mean, for me, it's
an exercise of science.

1401
00:54:21,020 --> 00:54:23,560
I feel I'm doing science
when I'm doing that

1402
00:54:23,560 --> 00:54:25,130
and clarifying my mind,

1403
00:54:25,130 --> 00:54:26,960
and reading of the great masters,

1404
00:54:26,960 --> 00:54:29,680
who were infinitely better than
me, I mean, reading Galileo,

1405
00:54:29,680 --> 00:54:31,500
when he wrote these books,

1406
00:54:31,500 --> 00:54:33,980
it seems to me he's doing
exactly the same thing.

1407
00:54:33,980 --> 00:54:36,030
I mean, he's talking to people.

1408
00:54:36,030 --> 00:54:40,270
That's a book written
for the cultivated person

1409
00:54:40,270 --> 00:54:43,120
of the European Renaissance
in the 17th Century,

1410
00:54:43,120 --> 00:54:45,580
not for his colleagues, astronomers,

1411
00:54:45,580 --> 00:54:48,240
because it explain things one by one,

1412
00:54:48,240 --> 00:54:51,330
but obviously it's debating
with his colleagues,

1413
00:54:51,330 --> 00:54:52,600
astronomers, in the book.

1414
00:54:52,600 --> 00:54:55,610
It's making the subtle
points of the argumentation,

1415
00:54:55,610 --> 00:54:57,293
proving him right and them wrong,

1416
00:54:57,293 --> 00:55:00,010
and that's what makes that book so great.

1417
00:55:00,010 --> 00:55:01,500
Now, of course, I'm not Galileo,

1418
00:55:01,500 --> 00:55:04,450
and I'm not writing the dialogue
of the two great systems,

1419
00:55:04,450 --> 00:55:06,440
but it's this kind of popular science,

1420
00:55:06,440 --> 00:55:07,890
which other people are doing,

1421
00:55:07,890 --> 00:55:11,960

which is presenting ideas in
a way which are comprehensible

1422

00:55:11,960 --> 00:55:14,800
to defend these ideas,
which I'm trying to do.

1423

00:55:14,800 --> 00:55:16,980
- Are you working on any books now?

1424

00:55:16,980 --> 00:55:19,769
- Yeah, I am, but I'm not
sure I should talk about that.

1425

00:55:19,769 --> 00:55:21,770
- (laughs) Are you always
working on one book or another?

1426

00:55:21,770 --> 00:55:24,030
- No, no, I have not been writing

1427

00:55:25,010 --> 00:55:26,750
for one year, or more.

1428

00:55:26,750 --> 00:55:28,280
I just stopped completely.

1429

00:55:28,280 --> 00:55:30,030
I am under strong pressure, of course,

1430

00:55:30,030 --> 00:55:33,050
from publishers and
things for writing more.

1431

00:55:33,050 --> 00:55:34,260
Let me just give you this,

1432

00:55:34,260 --> 00:55:36,430
I'm not covering a large

portion of physics,

1433

00:55:36,430 --> 00:55:37,950

I want to do the narration,

1434

00:55:37,950 --> 00:55:41,410

tell the story of how a
theoretical physicist like me

1435

00:55:41,410 --> 00:55:43,050

gets into a specific problem,

1436

00:55:43,050 --> 00:55:44,570

gets fascinated by the problem,

1437

00:55:44,570 --> 00:55:47,140

works through and comes
out with some ideas,

1438

00:55:47,140 --> 00:55:48,840

and is struggling on.

1439

00:55:48,840 --> 00:55:51,400

So, whether this particular thing

1440

00:55:51,400 --> 00:55:53,010

is right or wrong is irrelevant.

1441

00:55:53,010 --> 00:55:57,000

I want to tell how is
theoretical science in the doing.

1442

00:55:57,000 --> 00:55:58,620

- Sort of humanizing the process

1443

00:55:58,620 --> 00:56:00,640

or putting a-

- Yes, yes.

1444

00:56:00,640 --> 00:56:02,380

- Making it relatable to non-science.

1445

00:56:02,380 --> 00:56:05,130

- Yes, so what is actually going on,

1446

00:56:05,130 --> 00:56:08,220

including changing minds and realizing things didn't work,

1447

00:56:08,220 --> 00:56:10,560

and so on and so forth.

1448

00:56:10,560 --> 00:56:12,480

- I don't actually have any further questions.

1449

00:56:12,480 --> 00:56:14,810

We've kept you for more than an hour, I believe.

1450

00:56:14,810 --> 00:56:16,650

- Wonderful.

- So, thank you so much

1451

00:56:16,650 --> 00:56:19,110

for chatting with us.

- Thank you.

1452

00:56:19,110 --> 00:56:20,300

- I'll just ask a question

1453

00:56:20,300 --> 00:56:22,100

I always ask people when I interview them,

1454

00:56:22,100 --> 00:56:24,130

what keeps you up at night these days?

1455

00:56:24,130 --> 00:56:25,350
- Last night, I was awake

1456
00:56:25,350 --> 00:56:28,410
with (laughing) my going away.

1457
00:56:28,410 --> 00:56:30,120
- It was a relevant question.
- Yeah.

1458
00:56:30,120 --> 00:56:33,610
There is a beautiful
experiment in quantum gravity,

1459
00:56:33,610 --> 00:56:35,470
in fact, that's been proposed.

1460
00:56:35,470 --> 00:56:38,030
There are some people who
are questioning the way

1461
00:56:38,030 --> 00:56:40,670
to think about that, and
I think they're wrong.

1462
00:56:40,670 --> 00:56:44,590
So, I'm trying to find out a
right theoretical description

1463
00:56:44,590 --> 00:56:46,790
of this experiment, and in doing that,

1464
00:56:46,790 --> 00:56:48,910
it's fun because it's basic physics,

1465
00:56:48,910 --> 00:56:52,540
but it's the writing and
thinking I do in new ways,

1466

00:56:52,540 --> 00:56:54,810
and there are technical
issues, technical problems,

1467
00:56:54,810 --> 00:56:57,550
so I keep going around these things here.

1468
00:56:57,550 --> 00:56:59,360
So, it's not a big, huge question,

1469
00:56:59,360 --> 00:57:00,980
it's a very small, specific question.

1470
00:57:00,980 --> 00:57:03,060
- Well, we'll have to
have you back another time

1471
00:57:03,060 --> 00:57:05,460
so you can tell us, tell
us the results of that.

1472
00:57:06,300 --> 00:57:08,260
So, thank you again, this
has just been a pleasure.

1473
00:57:08,260 --> 00:57:09,580
- Thank you very much.
- Thank you.

1474
00:57:09,580 --> 00:57:10,654
- That was very nice.

1475
00:57:10,654 --> 00:57:14,590
(light electronic music)

1476
00:57:14,590 --> 00:57:17,350
- Thanks for listening to
Conversations at the Perimeter.

1477

00:57:17,350 --> 00:57:20,210
If you like what you hear,
please help us spread the word.

1478
00:57:20,210 --> 00:57:23,050
Rate, review and subscribe to
Conversations at the Perimeter

1479
00:57:23,050 --> 00:57:25,100
wherever you get your podcasts.

1480
00:57:25,100 --> 00:57:27,290
Every review helps us out a lot,

1481
00:57:27,290 --> 00:57:30,040
and it helps more science
enthusiasts find us.

1482
00:57:30,040 --> 00:57:31,863
Thanks for being part of the equation.

1483
00:57:31,863 --> 00:57:35,280
(light electronic music)