1
00:00:08,970 --> 00:00:10,532
Hi everyone, and welcome back

2
00:00:10,533 --> 00:00:12,826
to conversations at the perimeter.

3
00:00:12,827 --> 00:00:15,156
I'm Lauren Hayward and I'm excited to share

4
00:00:15,157 --> 00:00:17,754
a conversation I had with Neil Turok.

5
00:00:17,755 --> 00:00:19,748
Neil is currently a professor at the

6
00:00:19,749 --> 00:00:22,004
University of Edinburgh and he holds the

7
00:00:22,005 --> 00:00:24,202
Higgs chair of theoretical physics.

8
00:00:24,203 --> 00:00:26,722
He acted as the director of Perimeter Institute

9
00:00:26,723 --> 00:00:30,268
from 2008 to 2019 and now holds the

10
00:00:30,269 --> 00:00:33,938
Carlo Fidani Roger Penrose distinguished visiting research chair

11
00:00:33,939 --> 00:00:36,370
in theoretical physics at Perimeter.

12
00:00:36,371 --> 00:00:38,418
Neil works in the field of cosmology,

13
00:00:38,419 --> 00:00:40,608

and he develops theories that incorporate an

14
00:00:40,609 --> 00:00:43,408
underlying simplicity that he argues nature has

15
00:00:43,409 --> 00:00:45,638
revealed to us through observations.

16
00:00:45,639 --> 00:00:48,048
He talks about his recent work that describes the

17
00:00:48,049 --> 00:00:50,688
Big Bang, how his research has been influenced by

18
00:00:50,689 --> 00:00:53,508
Stephen Hawking, and why he chooses to work on

19
00:00:53,509 --> 00:00:56,324
theories that have the potential to be proven wrong.

20
00:00:56,325 --> 00:00:58,212
He also talks about his time as

21
00:00:58,213 --> 00:01:01,028
director of Perimeter Institute and describes the

22
00:01:01,029 --> 00:01:03,114
strategies he used to create a culture

23
00:01:03,115 --> 00:01:06,222
and community capable of fostering breakthroughs.

24
00:01:06,223 --> 00:01:08,952
It's a fascinating conversation, and Neil is

25
00:01:08,953 --> 00:01:11,262
uniquely gifted in describing both the biggest

26
00:01:11,263 --> 00:01:13,832
questions in theoretical physics and the best

27
00:01:13,833 --> 00:01:15,612
strategies for answering them.

28
00:01:15,613 --> 00:01:17,916
So without further ado, let's step

29
00:01:17,917 --> 00:01:20,550
inside the perimeter with Neil Turok.

30
00:01:23,290 --> 00:01:25,932
Hi, Neil Turok, thank you so much for

31
00:01:25,933 --> 00:01:28,498
joining us on conversations at the perimeter.

32
00:01:28,499 --> 00:01:29,506
My pleasure.

33
00:01:29,507 --> 00:01:32,278
So I have to say, I've always enjoyed when I've

34
00:01:32,279 --> 00:01:34,720
had the opportunity to talk to you over the years.

35
00:01:34,721 --> 00:01:38,592
And one thing that I find particularly impressive about your

36
00:01:38,593 --> 00:01:41,668
work is that you have such a deep understanding of

37
00:01:41,669 --> 00:01:45,530
the big picture and the goals of fundamental physics.

38
00:01:45,531 --> 00:01:48,762

I think this is particularly difficult for researchers

39
00:01:48,763 --> 00:01:50,212
like me that can maybe get a bit

40
00:01:50,213 --> 00:01:53,758
lost in technical difficulties and calculations.

41
00:01:53,759 --> 00:01:57,880
So I want to start with a very big picture question.

42
00:01:57,881 --> 00:01:58,488
Okay.

43
00:01:58,489 --> 00:02:00,520
How would you describe the state

44
00:02:00,521 --> 00:02:03,060
of theoretical physics research today?

45
00:02:03,590 --> 00:02:05,128
It's very interesting.

46
00:02:05,129 --> 00:02:07,580
It has grown into a very large field.

47
00:02:07,581 --> 00:02:09,138
There are tens of thousands

48
00:02:09,139 --> 00:02:11,370
of researchers around the world.

49
00:02:11,371 --> 00:02:12,540
At the same time.

50
00:02:12,541 --> 00:02:16,418
I think it's diversified enormously.

51
00:02:16,419 --> 00:02:19,744
The part of it which I'm most fascinated in

52
00:02:19,745 --> 00:02:24,032
is the fundamental understanding of the universe, be it

53
00:02:24,033 --> 00:02:27,856
on very small scales as in particle physics, or

54
00:02:27,857 --> 00:02:31,010
very large scales as in cosmology.

55
00:02:31,011 --> 00:02:33,092
And that part, I would have to say, has

56
00:02:33,093 --> 00:02:38,458
been, on the one hand, benefiting from incredible observations.

57
00:02:38,459 --> 00:02:40,052
On small scales, we have the large

58
00:02:40,053 --> 00:02:44,968
Hadron Collider, most powerful microscope ever built

59
00:02:44,969 --> 00:02:48,152
showing us what subatomic particles look like.

60
00:02:48,153 --> 00:02:51,198
And on the large scales, we have data showing

61
00:02:51,199 --> 00:02:55,794
us the whole visible universe with exquisite precision.

62
00:02:55,795 --> 00:02:59,770
So it's definitely been a golden age in that sense.

63
00:02:59,771 --> 00:03:02,658

But on the more theoretical side, I'd

64
00:03:02,659 --> 00:03:05,234
say the picture is more mixed.

65
00:03:05,235 --> 00:03:07,984
Since I started in theoretical physics in the

66
00:03:07,985 --> 00:03:11,222
early eighty s, there have been great hopes

67
00:03:11,223 --> 00:03:15,558
about a number of programs of research, grand

68
00:03:15,559 --> 00:03:20,790
unified theories, supersymmetric theories, string theory, super gravity,

69
00:03:20,791 --> 00:03:23,108
m theory, and so on.

70
00:03:23,109 --> 00:03:25,060
And I would have to say that

71
00:03:25,061 --> 00:03:27,284
these have not yet panned out.

72
00:03:27,285 --> 00:03:29,412
It's very striking that there is not

73
00:03:29,413 --> 00:03:33,672
yet a single prediction which has been

74
00:03:33,673 --> 00:03:37,294
verified from any of these frameworks.

75
00:03:37,295 --> 00:03:40,152
So, from my own point of view, on the one

76
00:03:40,153 --> 00:03:43,678
hand, you can wring your hands and say, why hasn't

77
00:03:43,679 --> 00:03:48,172
theory been more successful in the last 40 years?

78
00:03:48,173 --> 00:03:49,730
All the theories we've verified

79
00:03:49,731 --> 00:03:52,370
are essentially rather old theories.

80
00:03:52,371 --> 00:03:56,124
Einstein's theory of gravity, the Higgs theory of

81
00:03:56,125 --> 00:03:58,832
the Higgs boson, and the standard model have

82
00:03:58,833 --> 00:04:01,686
been verified with more and more precision.

83
00:04:01,687 --> 00:04:04,544
But the newer ideas haven't panned out.

84
00:04:04,545 --> 00:04:06,848
So you can feel rather

85
00:04:06,849 --> 00:04:10,294
upset and disappointed about that. I don't.

86
00:04:10,295 --> 00:04:14,212
I think what's happening is that nature is

87
00:04:14,213 --> 00:04:17,892
speaking to us and telling us that he

88
00:04:17,893 --> 00:04:22,324

or she is simpler than we expected, because

89
00:04:22,325 --> 00:04:27,214
what these observations reveal is a striking minimalism.

90
00:04:27,215 --> 00:04:30,070
We have not found any more particles

91
00:04:30,071 --> 00:04:33,342
probing the universe at very high energies.

92
00:04:33,343 --> 00:04:37,080
Now, at the large hadron collider, and on large scales in

93
00:04:37,081 --> 00:04:39,932
the universe, the universe appears to be more or less as

94
00:04:39,933 --> 00:04:43,628
simple as it possibly could be and still give rise to

95
00:04:43,629 --> 00:04:47,110
galaxies and stars and the structures we observe.

96
00:04:47,710 --> 00:04:50,832
So this is tremendously exciting, because I think

97
00:04:50,833 --> 00:04:55,472
the simplicity indicated by the observations is, I

98
00:04:55,473 --> 00:04:57,670
believe, pointing us to new principles.

99
00:04:57,671 --> 00:05:00,308
And those principles will be deep and

100
00:05:00,309 --> 00:05:04,986
universal and highly predictive and highly constraining,

101
00:05:04,987 --> 00:05:07,428
and they will constrain the universe to

102
00:05:07,429 --> 00:05:09,748
look something like what we see.

103
00:05:09,749 --> 00:05:12,548
Whereas you might naively expect the universe to get

104
00:05:12,549 --> 00:05:14,718
more and more complicated as you go to bigger

105
00:05:14,719 --> 00:05:17,672
scales, the opposite seems to be true.

106
00:05:17,673 --> 00:05:20,232
And that I find extremely exciting, because

107
00:05:20,233 --> 00:05:24,180
it means that maybe indeed, we are.

108
00:05:25,510 --> 00:05:28,498
The scales we live on and we operate

109
00:05:28,499 --> 00:05:31,538
on are perhaps in some sense, the leading

110
00:05:31,539 --> 00:05:34,194
edge of a complexity in the universe.

111
00:05:34,195 --> 00:05:37,728
Universe is much simpler on small scales, much simpler on

112
00:05:37,729 --> 00:05:41,950
large scales, and that helps put us in context.

113
00:05:41,951 --> 00:05:45,238

And maybe if we understand the big picture,

114
00:05:45,239 --> 00:05:49,152
the universe on very large scales, we will

115
00:05:49,153 --> 00:05:53,490
somehow understand where we sit in the universe.

116
00:05:53,491 --> 00:05:56,452
And I'm particularly excited about our

117
00:05:56,453 --> 00:05:59,002
recent work addressing the big bang.

118
00:05:59,003 --> 00:06:01,348
This is the most profound puzzle in all

119
00:06:01,349 --> 00:06:04,480
of physics, how everything emerged from a point.

120
00:06:05,010 --> 00:06:07,496
And I think over the last year or two,

121
00:06:07,497 --> 00:06:09,864
we've really started to make sense of that.

122
00:06:09,865 --> 00:06:13,768
And again, it indicates our new understanding is

123
00:06:13,769 --> 00:06:16,124
that the big bang is actually quite simple.

124
00:06:16,125 --> 00:06:20,732
It's not an arbitrary or chaotic or random process.

125
00:06:20,733 --> 00:06:23,020
I mean, if our theoretical ideas are correct,

126
00:06:23,021 --> 00:06:26,668
it's a very precise boundary condition for the

127
00:06:26,669 --> 00:06:31,334
universe, and a highly principled boundary condition.

128
00:06:31,335 --> 00:06:34,502
And if so, then the universe becomes

129
00:06:34,503 --> 00:06:37,690
much more comprehensible in its entirety.

130
00:06:38,270 --> 00:06:40,906
And as you said, many other researchers

131
00:06:40,907 --> 00:06:43,748
work on more complicated theories that are

132
00:06:43,749 --> 00:06:45,860
not embracing minimalism as much.

133
00:06:45,861 --> 00:06:48,772
Why do you think others tend to

134
00:06:48,773 --> 00:06:52,000
stray away from these simpler think?

135
00:06:52,690 --> 00:06:55,192
You know, we're all trying to follow the

136
00:06:55,193 --> 00:06:58,552
example set by Maxwell with Maxwell's equations, or

137
00:06:58,553 --> 00:07:02,206
Dirac with Dirac's equation, Einstein with Einstein's equation.

138
00:07:02,207 --> 00:07:06,942

These are tremendously principled, economical mathematical

139
00:07:06,943 --> 00:07:11,710
equations, which govern know bewildering variety

140
00:07:11,711 --> 00:07:14,610
of phenomena and extremely predictive.

141
00:07:14,611 --> 00:07:18,102
So we're all trying to emulate these highly

142
00:07:18,103 --> 00:07:22,208
successful theories we base our current theories on.

143
00:07:22,209 --> 00:07:25,766
But I think what happened is that particle theory,

144
00:07:25,767 --> 00:07:30,448
over the last 50 years, maybe longer, got into

145
00:07:30,449 --> 00:07:34,522
the habit of always postulating new particles.

146
00:07:34,523 --> 00:07:37,162
And to some extent, this was natural,

147
00:07:37,163 --> 00:07:38,708
because every time you built a new

148
00:07:38,709 --> 00:07:41,338
accelerator, you discovered new particles.

149
00:07:41,339 --> 00:07:44,456
And so this just became the norm, is that we expect

150
00:07:44,457 --> 00:07:47,214
once in a while to add a few new particles.

151
00:07:47,215 --> 00:07:51,838
And the hope arose that by adding these new particles,

152
00:07:51,839 --> 00:07:55,550
at some point we would actually simplify the picture.

153
00:07:55,551 --> 00:07:58,188
So, in grand unified theories, for example, you

154
00:07:58,189 --> 00:07:59,868
try to make sense of the pattern of

155
00:07:59,869 --> 00:08:02,674
particles around us by adding some more particles

156
00:08:02,675 --> 00:08:05,698
in such a way that the whole unified.

157
00:08:05,699 --> 00:08:09,222
And that habit sort of persisted, but it generalized.

158
00:08:09,223 --> 00:08:11,718
So instead of adding particles, people added

159
00:08:11,719 --> 00:08:16,662
extra dimensions of space and extra objects.

160
00:08:16,663 --> 00:08:18,832
So there were strings in string theory, and

161
00:08:18,833 --> 00:08:23,978
membranes and higher dimensional structures, which were added

162
00:08:23,979 --> 00:08:25,988
to these theories, all in the hope of

163
00:08:25,989 --> 00:08:28,370

sort of unifying this in a principle.

164
00:08:28,371 --> 00:08:32,154
However, the principles were somewhat lacking.

165
00:08:32,155 --> 00:08:37,172
So string theory, notoriously, doesn't really have a

166
00:08:37,173 --> 00:08:41,751
clear conceptual foundational principle, in the same way

167
00:08:41,752 --> 00:08:45,064
that Einstein's theory of gravity had.

168
00:08:45,065 --> 00:08:48,872
In Einstein's theory, the conception was that you

169
00:08:48,873 --> 00:08:52,562
have curved spacetime, and this curved spacetime tells

170
00:08:52,563 --> 00:08:55,292
matter how to move, and in turn, the

171
00:08:55,293 --> 00:08:57,618
matter tells the space time how to curve.

172
00:08:57,619 --> 00:09:01,228
That's how John Wheeler famously described it.

173
00:09:01,229 --> 00:09:04,912
And those know, besides being very beautiful, they

174
00:09:04,913 --> 00:09:08,848
capture a concept of how the physical world

175
00:09:08,849 --> 00:09:12,522
works, which is very intuitive and very powerful.

176
00:09:12,523 --> 00:09:13,812
And when it's translated into

177
00:09:13,813 --> 00:09:16,698
mathematics, it becomes highly predictive.

178
00:09:16,699 --> 00:09:21,588
But string theory has lacked such principles, and it's been

179
00:09:21,589 --> 00:09:24,376
more a question of sort of follow your nose, and

180
00:09:24,377 --> 00:09:27,358
when you come across some phenomenon, you sort of tweak

181
00:09:27,359 --> 00:09:31,110
the theory or you adjust your interpretation.

182
00:09:31,111 --> 00:09:36,988
And in particular in cosmology, quite a popular endeavor in

183
00:09:36,989 --> 00:09:41,218
string theory has been to try to picture the universe

184
00:09:41,219 --> 00:09:43,954
as if it was what's called an S matrix.

185
00:09:43,955 --> 00:09:45,516
An S matrix is something

186
00:09:45,517 --> 00:09:47,714
used to describe particle collisions.

187
00:09:47,715 --> 00:09:52,368
Things come in and things come out but I think the way

188
00:09:52,369 --> 00:09:58,208

the cosmos works seems very, very different to an S matrix, at

189
00:09:58,209 --> 00:10:00,996
least in the part of the universe we can see.

190
00:10:00,997 --> 00:10:03,898
There was a starting point, and there's

191
00:10:03,899 --> 00:10:07,572
this finishing point, which is dominated by

192
00:10:07,573 --> 00:10:10,826
the energy in empty space, the cosmological

193
00:10:10,827 --> 00:10:13,410
constant, sometimes called the dark energy.

194
00:10:13,411 --> 00:10:15,368
And so I think trying to shoehorn the

195
00:10:15,369 --> 00:10:19,742
universe into a preconceived picture which was designed

196
00:10:19,743 --> 00:10:23,448
for particle physics experiments, to me seems a

197
00:10:23,449 --> 00:10:25,368
sort of search for a principle, but not

198
00:10:25,369 --> 00:10:28,044
one that's particularly likely to work.

199
00:10:28,045 --> 00:10:30,700
So I think people have been trying to find

200
00:10:30,701 --> 00:10:34,940
principles which are economical and powerful and will explain

201
00:10:34,941 --> 00:10:37,292
lots of things, but to a large extent, those

202
00:10:37,293 --> 00:10:39,904
principles don't seem to be the right ones.

203
00:10:39,905 --> 00:10:44,430
And as I say, the enormous simplicity of nature

204
00:10:44,431 --> 00:10:48,886
is hinting that there are principles to be discovered.

205
00:10:48,887 --> 00:10:51,078
Yeah, I'm hopeful that we're beginning

206
00:10:51,079 --> 00:10:52,496
to get on the right track.

207
00:10:52,497 --> 00:10:55,162
I've heard you say that a key ingredient

208
00:10:55,163 --> 00:10:56,724
in doing this work is having a lot

209
00:10:56,725 --> 00:10:59,482
of dialogue between theorists and experimentalists.

210
00:10:59,483 --> 00:11:01,588
But this is not always easy to do, and

211
00:11:01,589 --> 00:11:03,748
I think there tends to be a bit of

212
00:11:03,749 --> 00:11:05,704
a divide between these areas of research.

213
00:11:05,705 --> 00:11:06,888

So how do you think we

214
00:11:06,889 --> 00:11:08,536
can improve this and have more

215
00:11:08,537 --> 00:11:12,206
effective collaborations between theorists and experimentalists?

216
00:11:12,207 --> 00:11:14,312
Well, I think it's difficult because both

217
00:11:14,313 --> 00:11:16,710
theory and experiment are very technical.

218
00:11:17,290 --> 00:11:19,788
When I started as a PhD student, it

219
00:11:19,789 --> 00:11:23,772
was very noticeable that the theorists where I

220
00:11:23,773 --> 00:11:26,562
were in imperial College had their own seminars,

221
00:11:26,563 --> 00:11:28,768
and the experimentalists had their own seminars, and

222
00:11:28,769 --> 00:11:31,814
they generally never went to each other's seminars.

223
00:11:31,815 --> 00:11:36,352
So the high level of technical complications in both

224
00:11:36,353 --> 00:11:40,220
aspects of science mean that people don't have time

225
00:11:41,170 --> 00:11:44,036
often, to interact much with each other.

226
00:11:44,037 --> 00:11:47,060
That's very sad, because I do believe that

227
00:11:47,061 --> 00:11:50,906
theoretical physics should be at its most exciting

228
00:11:50,907 --> 00:11:55,350
and most effective, should be connected to observations.

229
00:11:55,351 --> 00:11:58,318
And there's been an increasing sort of divergence

230
00:11:58,319 --> 00:12:02,056
of so called pure theory from observations, and

231
00:12:02,057 --> 00:12:05,496
even a sort of philosophical justification by saying,

232
00:12:05,497 --> 00:12:07,704
oh, well, if we know our theory is

233
00:12:07,705 --> 00:12:11,692
right for mathematical reasons, we don't really need

234
00:12:11,693 --> 00:12:14,330
to pay attention to the observations.

235
00:12:14,331 --> 00:12:16,556
I'm very critical of such point of view

236
00:12:16,557 --> 00:12:19,776
because I think you can really easily go

237
00:12:19,777 --> 00:12:24,176
wrong in your mathematical assumptions and very quickly

238
00:12:24,177 --> 00:12:27,174

just diverge from anything to do with reality.

239
00:12:27,175 --> 00:12:30,790
You need to keep one eye on the observations.

240
00:12:30,791 --> 00:12:34,560
It may not be in very detail, very much detail.

241
00:12:35,090 --> 00:12:37,428
You don't need to get involved in experiments or

242
00:12:37,429 --> 00:12:40,356
data analysis or whatever, but you need to pay

243
00:12:40,357 --> 00:12:46,168
very close attention to major observational results if you

244
00:12:46,169 --> 00:12:51,830
are to actually build a successful theoretical physics framework.

245
00:12:51,831 --> 00:12:55,070
So I think the field does need a bit of a reset.

246
00:12:55,071 --> 00:12:59,324
It's particularly important for students to sort of

247
00:12:59,325 --> 00:13:03,148
appreciate the wonder, the sort of miracle that

248
00:13:03,149 --> 00:13:06,412
theoretical physics is that when it does connect

249
00:13:06,413 --> 00:13:09,526
to reality, it's quite magical.

250
00:13:09,527 --> 00:13:13,504
And I think the students who don't pursue that

251
00:13:13,505 --> 00:13:17,728
or aspire to that are really missing out on

252
00:13:17,729 --> 00:13:21,408
a lot, that one should never forget that the

253
00:13:21,409 --> 00:13:23,658
real magic in the subject is when it connects

254
00:13:23,659 --> 00:13:28,122
to observations, and these observations, extremely fundamental.

255
00:13:28,123 --> 00:13:30,596
I mean, we know things about the universe that

256
00:13:30,597 --> 00:13:33,048
the fact that empty space seems to have an

257
00:13:33,049 --> 00:13:37,270
energy, the cosmological constant, that's very profound.

258
00:13:37,271 --> 00:13:39,624
There are ideas, again, for

259
00:13:39,625 --> 00:13:41,736
interpreting the meaning of that.

260
00:13:41,737 --> 00:13:44,820
What is this stuff in empty space?

261
00:13:45,350 --> 00:13:47,976
Then we have the dark matter, very good

262
00:13:47,977 --> 00:13:50,012
observations showing us that most of the matter

263
00:13:50,013 --> 00:13:53,450

in galaxies doesn't interact with light.

264
00:13:53,451 --> 00:13:55,442
And we have some very interesting candidates

265
00:13:55,443 --> 00:13:56,988
for the dark matter, some of which

266
00:13:56,989 --> 00:13:59,686
are very minimal, like neutrinos.

267
00:13:59,687 --> 00:14:03,040
We know neutrinos exist, and it's a very simple

268
00:14:03,041 --> 00:14:05,952
and natural idea that one of the so called

269
00:14:05,953 --> 00:14:08,528
right handed neutrinos is the dark matter.

270
00:14:08,529 --> 00:14:12,468
And the exciting thing is that that hypothesis is possible

271
00:14:12,469 --> 00:14:15,716
to test within the next five years or so.

272
00:14:15,717 --> 00:14:19,332
People are projecting that through observations of

273
00:14:19,333 --> 00:14:23,300
galaxy clustering, one can actually detect even

274
00:14:23,301 --> 00:14:26,798
very tiny light neutrino masses.

275
00:14:26,799 --> 00:14:29,848
And if one of the right handed neutrinos is

276
00:14:29,849 --> 00:14:32,776
the dark matter, and if it's stable, then it

277
00:14:32,777 --> 00:14:34,856
follows as a consequence that one of the light

278
00:14:34,857 --> 00:14:37,868
neutrinos is massless, and that should be possible to

279
00:14:37,869 --> 00:14:39,596
confirm within the next five years.

280
00:14:39,597 --> 00:14:43,132
It's very, very challenging work for people doing

281
00:14:43,133 --> 00:14:46,290
the observations and modeling, a lot of computational

282
00:14:46,291 --> 00:14:49,558
modeling to understand how the light neutrino masses

283
00:14:49,559 --> 00:14:51,870
affect the clumping of matter.

284
00:14:51,871 --> 00:14:54,688
But so far, the predictions are that with the

285
00:14:54,689 --> 00:14:58,112
anticipated accuracy of the measurements, we should be able

286
00:14:58,113 --> 00:15:02,032
to tell quite definitively within five years or so

287
00:15:02,033 --> 00:15:03,802
whether the light neutrinos are massless.

288
00:15:03,803 --> 00:15:07,028

And if that is confirmed, it will be

289
00:15:07,029 --> 00:15:09,508
a very strong indication that we're actually on

290
00:15:09,509 --> 00:15:11,364
the road to understanding the dark matter.

291
00:15:11,365 --> 00:15:12,968
And then there are other things, like the

292
00:15:12,969 --> 00:15:15,342
fluctuations coming out of the big bang.

293
00:15:15,343 --> 00:15:19,944
These take the form of quantum fluctuations in the

294
00:15:19,945 --> 00:15:23,928
vacuum, which is a very profound phenomenon that the

295
00:15:23,929 --> 00:15:26,588
quantum fields we observe, like the electron or the

296
00:15:26,589 --> 00:15:30,220
photon, all the other fields in the standard model

297
00:15:30,221 --> 00:15:32,322
have fluctuations in the vacuum.

298
00:15:32,323 --> 00:15:34,860
And these are very paradoxical and

299
00:15:34,861 --> 00:15:37,202
strange, have very strange properties.

300
00:15:37,203 --> 00:15:39,248
For example, that if you add up all the

301
00:15:39,249 --> 00:15:45,270
energy in these vacuum zero point fluctuations, it's infinite.

302
00:15:45,271 --> 00:15:48,198
And that doesn't make any sense, because gravity couples

303
00:15:48,199 --> 00:15:51,734
to energy, and gravity would see that infinity.

304
00:15:51,735 --> 00:15:54,532
So for decades, we've been sweeping this under

305
00:15:54,533 --> 00:15:56,676
the rug and pretending it's not really there,

306
00:15:56,677 --> 00:15:59,730
and so called renormalizing it away.

307
00:15:59,731 --> 00:16:01,812
This is not a good state of affairs, because

308
00:16:01,813 --> 00:16:04,094
it means we do not have a physical picture

309
00:16:04,095 --> 00:16:06,950
of what's going on in the vacuum.

310
00:16:06,951 --> 00:16:09,518
And again, these new developments, some of which I've

311
00:16:09,519 --> 00:16:13,416
been involved in, are pointing to resolution of these

312
00:16:13,417 --> 00:16:17,948
questions, so that by modifying the vacuum of the

313
00:16:17,949 --> 00:16:21,148

standard model in a certain, very precise way, you

314
00:16:21,149 --> 00:16:26,588
can cancel this energy divergence and, in fact, protect

315
00:16:26,589 --> 00:16:29,824
some of the deep symmetries in the standard model,

316
00:16:29,825 --> 00:16:33,206
one of which is called local scale symmetry.

317
00:16:33,207 --> 00:16:37,856
So it's a surprising fact that a photon of light

318
00:16:37,857 --> 00:16:39,792
is pretty much the same as a photon of x

319
00:16:39,793 --> 00:16:43,028
rays or radio waves, and they're all just scaled up

320
00:16:43,029 --> 00:16:45,780
or down versions of exactly the same thing.

321
00:16:45,781 --> 00:16:48,490
That's a very deep symmetry of Maxwell's equations,

322
00:16:48,491 --> 00:16:50,852
that it's so called scale invariant, and even

323
00:16:50,853 --> 00:16:53,306
more than that, locally scale invariant.

324
00:16:53,307 --> 00:16:55,662
So you can change the scale differently

325
00:16:55,663 --> 00:16:57,816
in different parts of space and time,

326
00:16:57,817 --> 00:17:00,550
and the equations remain the same.

327
00:17:00,551 --> 00:17:02,302
Why is that such a deep symmetry?

328
00:17:02,303 --> 00:17:05,612
Well, to describe the Big Bang, where everything came from

329
00:17:05,613 --> 00:17:09,356
a point, if all the material in the universe was

330
00:17:09,357 --> 00:17:13,867
insensitive to the overall size of the universe, as it

331
00:17:13,868 --> 00:17:17,867
is for Maxwell's theory, or actually for Dirac's theory as

332
00:17:17,868 --> 00:17:21,872
well, then the stuff in the universe doesn't know about

333
00:17:21,873 --> 00:17:23,568
the size of the universe at all.

334
00:17:23,569 --> 00:17:25,791
So even though, from our point of view, it

335
00:17:25,792 --> 00:17:29,440
all shrank to a point, the stuff of which

336
00:17:29,441 --> 00:17:33,946
matter is made doesn't see the so called singularity.

337
00:17:33,947 --> 00:17:38,506
And this makes the singularity possible to model mathematically

338
00:17:38,507 --> 00:17:42,202

and to really understand and to understand this boundary

339
00:17:42,203 --> 00:17:45,110
condition I mentioned at the Big Bang.

340
00:17:45,111 --> 00:17:48,632
So I think these principles, in other words, trying

341
00:17:48,633 --> 00:17:53,150
to deal with the vacuum energy infinity or divergence,

342
00:17:53,151 --> 00:17:56,088
trying to deal with the big Bang singularity, these

343
00:17:56,089 --> 00:17:58,956
are really pointing us to the right principles, which

344
00:17:58,957 --> 00:18:02,170
will explain the universe on large scales.

345
00:18:02,171 --> 00:18:04,162
The thing I'm most excited about recently

346
00:18:04,163 --> 00:18:06,722
is that using these same principles, we've

347
00:18:06,723 --> 00:18:09,872
been able to calculate the fluctuations we

348
00:18:09,873 --> 00:18:12,830
now see in the cosmic microwave background.

349
00:18:12,831 --> 00:18:16,208
And amazingly, the numbers come out correct.

350
00:18:16,209 --> 00:18:18,608
We get the right size of fluctuations, we get

351
00:18:18,609 --> 00:18:22,644
the right spectrum without any free parameters at all.

352
00:18:22,645 --> 00:18:25,834
And so this is early days, but it's

353
00:18:25,835 --> 00:18:28,692
a very exciting framework which may end up

354
00:18:28,693 --> 00:18:32,724
explaining the universe and connecting it to the

355
00:18:32,725 --> 00:18:35,800
fundamental physics of particles in a much more

356
00:18:35,801 --> 00:18:39,368
precise way than we ever thought was possible.

357
00:18:39,369 --> 00:18:42,936
And is this something that you have been working

358
00:18:42,937 --> 00:18:45,768
towards your whole career, trying to work on these

359
00:18:45,769 --> 00:18:49,010
very simple models with very few free parameters?

360
00:18:49,011 --> 00:18:50,652
Or would you say this is something

361
00:18:50,653 --> 00:18:53,602
that you've been exploring more recently.

362
00:18:53,603 --> 00:18:55,692
Essentially, I have been working with the

363
00:18:55,693 --> 00:18:58,342

same motivation for my whole career.

364
00:18:58,343 --> 00:19:00,998
I've always chosen to work on testable

365
00:19:00,999 --> 00:19:05,230
theories, even when most people don't.

366
00:19:05,231 --> 00:19:07,846
And so, as a student, I was very fascinated

367
00:19:07,847 --> 00:19:12,932
by an idea of my professor, Tom Kibble, that

368
00:19:12,933 --> 00:19:15,482
there would be cosmic defects in the universe.

369
00:19:15,483 --> 00:19:17,578
This was actually a consequence

370
00:19:17,579 --> 00:19:19,578
of grand unified theories.

371
00:19:19,579 --> 00:19:21,332
And what was exciting about it is

372
00:19:21,333 --> 00:19:23,060
if grand unified theories were correct.

373
00:19:23,061 --> 00:19:25,256
And if these defects had formed as they

374
00:19:25,257 --> 00:19:27,864
predicted, we would be able to see them.

375
00:19:27,865 --> 00:19:29,688
And so I spent a lot of time trying to

376
00:19:29,689 --> 00:19:34,958
calculate what they would look like, what observations would detect.

377
00:19:34,959 --> 00:19:38,008
And in the end, we disproved the idea

378
00:19:38,009 --> 00:19:41,212
that these defects gave rise to galaxies, which

379
00:19:41,213 --> 00:19:44,828
was one of the popular theories of the.

380
00:19:44,829 --> 00:19:46,092
Spent a lot of time trying to

381
00:19:46,093 --> 00:19:48,236
calculate precisely what the predictions were.

382
00:19:48,237 --> 00:19:50,592
And then when the experiments came along to

383
00:19:50,593 --> 00:19:53,392
check, they just proved those theories wrong.

384
00:19:53,393 --> 00:19:55,552
So I was very fortunate to work

385
00:19:55,553 --> 00:19:58,256
on theories which could be proven wrong.

386
00:19:58,257 --> 00:20:00,880
Then, when string theory came along, like

387
00:20:00,881 --> 00:20:02,694
most other people, I was very excited.

388
00:20:02,695 --> 00:20:04,852

Maybe this unified framework that

389
00:20:04,853 --> 00:20:06,180
really will explain everything.

390
00:20:06,181 --> 00:20:07,972
Is a theory of everything.

391
00:20:07,973 --> 00:20:09,796
And I did my best to try

392
00:20:09,797 --> 00:20:13,750
to reconcile string theory with cosmology.

393
00:20:13,751 --> 00:20:15,368
So we made a model of

394
00:20:15,369 --> 00:20:18,450
colliding brains in extra dimensions.

395
00:20:19,030 --> 00:20:20,632
And I would say at that point,

396
00:20:20,633 --> 00:20:23,750
I was beginning not really to believe.

397
00:20:23,751 --> 00:20:26,508
I didn't necessarily believe this framework, but I

398
00:20:26,509 --> 00:20:30,460
thought it was an interesting exercise to create

399
00:20:30,461 --> 00:20:34,226
a rival, a competitor to the most popular

400
00:20:34,227 --> 00:20:36,178
theory, which was called inflation.

401
00:20:36,179 --> 00:20:39,152
And hopefully one that was less adjustable and

402
00:20:39,153 --> 00:20:43,798
more connected to very fundamental physics, as string

403
00:20:43,799 --> 00:20:46,736
theory was quantum gravity and so on.

404
00:20:46,737 --> 00:20:49,584
But I think the realization slowly dawned that

405
00:20:49,585 --> 00:20:53,892
this whole framework was too complex, especially as

406
00:20:53,893 --> 00:20:57,490
the observations have become simpler and simpler.

407
00:20:57,491 --> 00:21:01,172
And the kind of signals you would have

408
00:21:01,173 --> 00:21:05,576
expected from inflation have progressively gone away.

409
00:21:05,577 --> 00:21:09,112
So one of inflation's predictions was that there

410
00:21:09,113 --> 00:21:12,894
should be very long wavelength gravitational waves.

411
00:21:12,895 --> 00:21:15,602
Created a sort of aftershock of this burst

412
00:21:15,603 --> 00:21:19,210
of expansion in the beginning of the universe.

413
00:21:19,211 --> 00:21:21,212

And you could see these long

414
00:21:21,213 --> 00:21:24,812
wavelength gravitational waves through observing the

415
00:21:24,813 --> 00:21:27,910
polarization of the microwave background sky.

416
00:21:28,430 --> 00:21:31,702
And the measurements finally became accurate

417
00:21:31,703 --> 00:21:33,472
enough to see this effect.

418
00:21:33,473 --> 00:21:35,872
Initially, they claimed they had seed it.

419
00:21:35,873 --> 00:21:39,286
And so all the inflationists were very excited

420
00:21:39,287 --> 00:21:42,442
and know this is verification, including Stephen Hawking.

421
00:21:42,443 --> 00:21:45,252
My friend Stephen Hawking bet me in

422
00:21:45,253 --> 00:21:48,228
public, or we had a bet.

423
00:21:48,229 --> 00:21:49,668
I had bet they would not see it,

424
00:21:49,669 --> 00:21:51,348
and they now claim to see it.

425
00:21:51,349 --> 00:21:53,940
And so he wanted me to pay the.

426
00:21:53,941 --> 00:21:57,890
I said, you know, all experiments require confirmation.

427
00:21:59,030 --> 00:22:01,710
And there were reasons to doubt this experiment.

428
00:22:01,711 --> 00:22:04,072
In the end, the experiment turned out to be wrong.

429
00:22:04,073 --> 00:22:06,572
And now what's happened is that

430
00:22:06,573 --> 00:22:08,844
the latest experiments see nothing.

431
00:22:08,845 --> 00:22:13,212
And within five years or so, the upper limit on

432
00:22:13,213 --> 00:22:16,844
these gravitational waves is going to get so low that

433
00:22:16,845 --> 00:22:21,232
I think most sort of relatively unbiased people will draw

434
00:22:21,233 --> 00:22:24,464
the conclusion that inflation probably isn't the way to go.

435
00:22:24,465 --> 00:22:26,150
So that's really exciting.

436
00:22:26,151 --> 00:22:28,448
The precision of the experiments has got to

437
00:22:28,449 --> 00:22:31,878
the point where large numbers of popular theoretical

438
00:22:31,879 --> 00:22:34,646

frameworks are now under severe pressure.

439
00:22:34,647 --> 00:22:37,108
All these things influence me a lot.

440
00:22:37,109 --> 00:22:40,170
But I think, especially when I was working at perimeter

441
00:22:40,171 --> 00:22:43,012
and I had the responsibility as director, of sort of

442
00:22:43,013 --> 00:22:46,584
deciding which fields were worthwhile to invest in.

443
00:22:46,585 --> 00:22:48,488
That made me look very critically at

444
00:22:48,489 --> 00:22:50,286
the whole field of theoretical physics.

445
00:22:50,287 --> 00:22:53,240
And try to assess where the best prospects were.

446
00:22:53,241 --> 00:22:55,432
And, of course, that influenced my research.

447
00:22:55,433 --> 00:22:58,296
And so when I left as director and I went back

448
00:22:58,297 --> 00:23:01,708
to full time research, I was very determined to focus on

449
00:23:01,709 --> 00:23:05,266
theories which I sort of genuinely believe are promising.

450
00:23:05,267 --> 00:23:07,404
And have a chance of

451
00:23:07,405 --> 00:23:11,372
providing very large explanatory power.

452
00:23:11,373 --> 00:23:13,312
And so that's what I'm working on.

453
00:23:13,313 --> 00:23:15,104
And I know you've said that a lot of

454
00:23:15,105 --> 00:23:17,872
the work you're doing now relies heavily on some

455
00:23:17,873 --> 00:23:20,976
ideas introduced by Stephen Hawking, who you already mentioned.

456
00:23:20,977 --> 00:23:23,220
Can you say a little more on that? Yes.

457
00:23:23,221 --> 00:23:25,332
I was very fortunate, in many

458
00:23:25,333 --> 00:23:27,290
ways to know Stephen Hawking.

459
00:23:27,291 --> 00:23:28,746
When I was an undergraduate.

460
00:23:28,747 --> 00:23:32,522
I went to his inaugural lecture, called very provocatively,

461
00:23:32,523 --> 00:23:34,954
is the end of theoretical Physics in sight?

462
00:23:34,955 --> 00:23:37,830
And it was sort of lecture, full of jokes.

463
00:23:37,831 --> 00:23:40,830

And at the end, he concluded it was in sight.

464
00:23:40,831 --> 00:23:42,846
And I was worried I'd missed the boat.

465
00:23:42,847 --> 00:23:44,792
They'd sorted everything out. It was super.

466
00:23:44,793 --> 00:23:47,500
Gravity was the answer, and that was that.

467
00:23:47,501 --> 00:23:50,514
But it proved to be over optimistic.

468
00:23:50,515 --> 00:23:52,562
And then later, I went back to Cambridge

469
00:23:52,563 --> 00:23:55,026
as a professor and made friends with Stephen,

470
00:23:55,027 --> 00:23:57,480
and we wrote several papers together.

471
00:23:58,010 --> 00:24:03,008
But what's special about Stephen is he

472
00:24:03,009 --> 00:24:05,376
was extremely adventurous at the time.

473
00:24:05,377 --> 00:24:08,784
He started thinking about quantum gravity and

474
00:24:08,785 --> 00:24:11,140
black holes and how they radiate, and

475
00:24:11,141 --> 00:24:13,530
the thermodynamics of black holes.

476
00:24:13,531 --> 00:24:16,628
That was far ahead of its time.

477
00:24:16,629 --> 00:24:18,628
But his ideas were so deep, they

478
00:24:18,629 --> 00:24:21,970
have influenced a whole field for decades.

479
00:24:21,971 --> 00:24:23,322
I think we're still struggling

480
00:24:23,323 --> 00:24:25,284
to understand what they mean.

481
00:24:25,285 --> 00:24:26,420
And he was, too.

482
00:24:26,421 --> 00:24:28,008
We still don't really know what the

483
00:24:28,009 --> 00:24:30,568
entropy of a black hole means exactly.

484
00:24:30,569 --> 00:24:32,936
We think it's to do with how many different

485
00:24:32,937 --> 00:24:35,006
ways there are to make a black hole.

486
00:24:35,007 --> 00:24:37,708
But we still can't quite put our finger on

487
00:24:37,709 --> 00:24:40,498
it, on exactly what it means and how it's

488
00:24:40,499 --> 00:24:42,962

compatible with all of the rest of physics.

489
00:24:42,963 --> 00:24:45,468
But in our very recent work, and

490
00:24:45,469 --> 00:24:48,918
this is with Latham, Boyle at perimeter.

491
00:24:48,919 --> 00:24:51,872
We've developed Stephen Hawking's concept of

492
00:24:51,873 --> 00:24:55,472
entropy, gravitational entropy, to apply to

493
00:24:55,473 --> 00:24:58,470
the universe, the whole universe.

494
00:24:58,471 --> 00:25:00,438
And that's been really surprising.

495
00:25:00,439 --> 00:25:03,178
And in the course of that study, I've

496
00:25:03,179 --> 00:25:07,786
come to the conclusion that Stephen himself underestimated

497
00:25:07,787 --> 00:25:09,550
the power of his own ideas.

498
00:25:10,770 --> 00:25:12,772
So he developed the idea of

499
00:25:12,773 --> 00:25:15,764
entropy, of gravitational entropy, entropy of

500
00:25:15,765 --> 00:25:17,802
black holes, entropy of the universe.

501
00:25:17,803 --> 00:25:20,388
He never succeeded in calculating it for

502
00:25:20,389 --> 00:25:22,610
the universe as we now have.

503
00:25:22,611 --> 00:25:26,450
And so he tied his idea is to inflation.

504
00:25:26,451 --> 00:25:29,148
Inflation, sort of, to put it bluntly, was the

505
00:25:29,149 --> 00:25:33,202
sort of ragbag of models, thousands of different models

506
00:25:33,203 --> 00:25:35,708
of inflation, all of them sort of tweaked and

507
00:25:35,709 --> 00:25:38,512
adjusted and with lots of assumptions to sort of

508
00:25:38,513 --> 00:25:41,470
fit what we see in the universe.

509
00:25:41,471 --> 00:25:43,952
And my current understanding is,

510
00:25:43,953 --> 00:25:45,264
you just don't need it.

511
00:25:45,265 --> 00:25:47,334
You don't need to tie Stephen's

512
00:25:47,335 --> 00:25:50,054
ideas of gravitational entropy to inflation.

513
00:25:50,055 --> 00:25:53,188

Just take them as they are, apply them to

514
00:25:53,189 --> 00:25:57,978
the real universe without any extra particles or fields

515
00:25:57,979 --> 00:26:01,812
or inflation or anything, and they already explain why

516
00:26:01,813 --> 00:26:05,200
the universe is big, smooth, and flat in themselves.

517
00:26:05,730 --> 00:26:07,668
And so that's been very exciting, is

518
00:26:07,669 --> 00:26:09,438
that I think we've found that Stephen's

519
00:26:09,439 --> 00:26:12,654
ideas are more powerful than he suspected.

520
00:26:12,655 --> 00:26:14,968
There are still questions about exactly what it all

521
00:26:14,969 --> 00:26:18,588
means, but it looks like they can explain the

522
00:26:18,589 --> 00:26:22,978
structure of the universe without any additional input.

523
00:26:22,979 --> 00:26:25,724
And then the other thing in what we're studying, you

524
00:26:25,725 --> 00:26:29,052
see, Stephen's ideas were very paradoxical in many ways.

525
00:26:29,053 --> 00:26:31,968
So he said, a black hole, which only has

526
00:26:31,969 --> 00:26:35,072
a mass, an angular momentum, an electric charge, just

527
00:26:35,073 --> 00:26:37,702
certain numbers it has, and it's featureless.

528
00:26:37,703 --> 00:26:40,208
A black hole is essentially featureless object, like

529
00:26:40,209 --> 00:26:42,880
an elementary particle, but it can be huge.

530
00:26:43,570 --> 00:26:47,280
This black hole can be made in so many ways.

531
00:26:47,890 --> 00:26:51,946
Now, the weird thing about that statement is that surely

532
00:26:51,947 --> 00:26:53,882
the number of ways you can make a black hole

533
00:26:53,883 --> 00:26:57,300
depends on how many different elementary particles there are.

534
00:26:57,301 --> 00:26:59,022
If I've only got one type of particle,

535
00:26:59,023 --> 00:27:00,734
I can make a certain black hole.

536
00:27:00,735 --> 00:27:02,990
But if I've got two types of particles, surely

537
00:27:02,991 --> 00:27:05,102
there are more ways to make a black hole.

538
00:27:05,103 --> 00:27:06,984

So just assigning an entropy of a

539
00:27:06,985 --> 00:27:09,346
black hole immediately creates a puzzle.

540
00:27:09,347 --> 00:27:11,356
Why are there so many different

541
00:27:11,357 --> 00:27:13,610
particles in the standard model?

542
00:27:13,611 --> 00:27:15,858
And does the entropy of black hole

543
00:27:15,859 --> 00:27:17,724
depend on how many particles there are?

544
00:27:17,725 --> 00:27:21,280
So the answer is, in his calculation, it's one result.

545
00:27:21,281 --> 00:27:22,656
You can't adjust it.

546
00:27:22,657 --> 00:27:24,112
You can't change the entropy by

547
00:27:24,113 --> 00:27:25,702
changing the number of particles.

548
00:27:25,703 --> 00:27:28,646
It's whatever it is that actually implies.

549
00:27:28,647 --> 00:27:30,948
I believe that the number of particles in

550
00:27:30,949 --> 00:27:34,426
the standard model is fixed by gravity.

551
00:27:34,427 --> 00:27:37,226
And we know there are three generations of particles.

552
00:27:37,227 --> 00:27:39,674
There are 16 particles per generation.

553
00:27:39,675 --> 00:27:43,524
That number should be forced on you by

554
00:27:43,525 --> 00:27:46,050
the fact the standard model couples to gravity.

555
00:27:46,630 --> 00:27:48,472
If it is, then the whole thing

556
00:27:48,473 --> 00:27:50,872
is absolutely self contained, and you just

557
00:27:50,873 --> 00:27:54,648
can't separate these puzles from each other.

558
00:27:54,649 --> 00:27:56,648
So, particle physicists who are trying to

559
00:27:56,649 --> 00:27:58,648
understand how many particles there are in

560
00:27:58,649 --> 00:28:01,948
nature, that question is meaningless unless you

561
00:28:01,949 --> 00:28:04,588
include gravity and gravitational theorists trying to

562
00:28:04,589 --> 00:28:06,690
understand the entropy of black hole.

563
00:28:06,691 --> 00:28:09,728

That question's meaningless unless you actually use the

564
00:28:09,729 --> 00:28:11,980
real number of particles in the world.

565
00:28:12,510 --> 00:28:14,752
So I think that, again, the fact

566
00:28:14,753 --> 00:28:17,392
that Stephen's entropy ideas seem to be

567
00:28:17,393 --> 00:28:20,548
successful in describing a universe indicates that

568
00:28:20,549 --> 00:28:23,978
physics is truly unified and not adjustable.

569
00:28:23,979 --> 00:28:27,652
And so if all of this works, I would say

570
00:28:27,653 --> 00:28:31,642
we will be pretty sure that this is the entirety

571
00:28:31,643 --> 00:28:35,224
of physics, because if you add another particle, you're going

572
00:28:35,225 --> 00:28:38,638
to spoil all these cancellations and agreements.

573
00:28:38,639 --> 00:28:42,008
So that's very exciting that nature may itself

574
00:28:42,009 --> 00:28:45,368
be telling us how things unify, and that

575
00:28:45,369 --> 00:28:48,818
all these kind of consistency arguments and arguments

576
00:28:48,819 --> 00:28:50,716
about the universe and the big bang and

577
00:28:50,717 --> 00:28:53,228
consistency with observations may, in fact, all come

578
00:28:53,229 --> 00:28:57,762
together very beautifully into a coherent mathematical picture.

579
00:28:57,763 --> 00:28:59,452
I want to go back to something you said

580
00:28:59,453 --> 00:29:01,298
a few minutes ago that I really liked.

581
00:29:01,299 --> 00:29:03,536
You said you feel lucky when you work

582
00:29:03,537 --> 00:29:05,584
on a theory that can be proven wrong.

583
00:29:05,585 --> 00:29:07,472
And I like that because I think

584
00:29:07,473 --> 00:29:10,000
it's very different from how many other

585
00:29:10,001 --> 00:29:12,176
researchers would feel in that situation.

586
00:29:12,177 --> 00:29:15,188
Many others would feel very scared when they

587
00:29:15,189 --> 00:29:17,572
think they can just be disproven at any

588
00:29:17,573 --> 00:29:20,628

moment with any new data that comes in.

589
00:29:20,629 --> 00:29:22,794
Why do you think it's so scary?

590
00:29:22,795 --> 00:29:26,488
For some people, the thought of being proven wrong, you

591
00:29:26,489 --> 00:29:30,130
know, it's a funny thing, but reality is scary.

592
00:29:30,790 --> 00:29:33,528
I don't quite know how to put it, but sometimes when

593
00:29:33,529 --> 00:29:38,284
you, for example, just go out into know, be it a

594
00:29:38,285 --> 00:29:42,562
snowy field in the middle of winter in Canada, or you're

595
00:29:42,563 --> 00:29:45,964
hiking in some tall mountain range or something, or you just

596
00:29:45,965 --> 00:29:50,508
look into empty space from earth and you think, wow, this

597
00:29:50,509 --> 00:29:53,130
is know that can feel scary.

598
00:29:53,710 --> 00:29:55,734
So, reality is scary.

599
00:29:55,735 --> 00:29:58,656
And I think it's as simple as saying, I do

600
00:29:58,657 --> 00:30:02,362
want physics to be real, and reality is scary.

601
00:30:02,363 --> 00:30:04,340
So we just have to face up to that.

602
00:30:04,341 --> 00:30:06,468
The way to face up to it is to sort

603
00:30:06,469 --> 00:30:13,016
of enjoy this kind of amazing fact that we are

604
00:30:13,017 --> 00:30:17,300
able to interact with nature and make sense of it.

605
00:30:17,910 --> 00:30:19,112
We don't understand why.

606
00:30:19,113 --> 00:30:20,744
We haven't got a clue why we can

607
00:30:20,745 --> 00:30:25,496
do that, except perhaps we've evolved capacities which

608
00:30:25,497 --> 00:30:27,148
somehow allow us to do that.

609
00:30:27,149 --> 00:30:29,218
But then they go way beyond

610
00:30:29,219 --> 00:30:32,002
what we ever needed to survive.

611
00:30:32,003 --> 00:30:34,370
So we have a scary capacity.

612
00:30:34,371 --> 00:30:35,436
That's obviously true.

613
00:30:35,437 --> 00:30:38,252

We can do all kinds of scary things, but

614
00:30:38,253 --> 00:30:41,814
I think part of just essentially being a responsible

615
00:30:41,815 --> 00:30:45,424
citizen and living up to the opportunity of life,

616
00:30:45,425 --> 00:30:48,592
which we all possess as a miracle, we all

617
00:30:48,593 --> 00:30:50,628
have this amazing thing called life.

618
00:30:50,629 --> 00:30:53,306
And I think just living up to that is facing

619
00:30:53,307 --> 00:30:59,092
these scary realities and trying to deal well with them.

620
00:30:59,093 --> 00:31:04,390
So I do see this, particularly among students,

621
00:31:04,391 --> 00:31:07,982
a sort of nervousness, particularly about career.

622
00:31:07,983 --> 00:31:11,502
People say, if I work on a theoretical

623
00:31:11,503 --> 00:31:14,318
framework, which a may be risky, maybe it's

624
00:31:14,319 --> 00:31:17,220
going to be mathematically shown to be wrong.

625
00:31:17,770 --> 00:31:20,754
That's probably the more immediate danger, because there's

626
00:31:20,755 --> 00:31:23,218
a lot more mathematics than there is physics,

627
00:31:23,219 --> 00:31:25,042
and there are lots more models of physics

628
00:31:25,043 --> 00:31:28,482
than there are real, correct models of physics.

629
00:31:28,483 --> 00:31:31,728
So I think for students, sometimes it's more comfortable to

630
00:31:31,729 --> 00:31:34,576
work on a model or a mathematical framework, which actually,

631
00:31:34,577 --> 00:31:37,790
nobody is going to prove wrong anytime soon.

632
00:31:37,791 --> 00:31:41,168
But those frameworks, what I would say, are often very

633
00:31:41,169 --> 00:31:44,610
unlikely to actually have much to do with reality.

634
00:31:44,611 --> 00:31:47,028
And so you'll be in a sort of

635
00:31:47,029 --> 00:31:50,932
relatively comfortable place, but you'll never experience the

636
00:31:50,933 --> 00:31:53,540
magic that the field is capable of.

637
00:31:54,070 --> 00:31:57,118
So this kind of search for safety

638
00:31:57,119 --> 00:32:00,462

is now very common across society.

639
00:32:00,463 --> 00:32:03,288
People don't necessarily want to

640
00:32:03,289 --> 00:32:05,032
deal with the difficult problems.

641
00:32:05,033 --> 00:32:07,532
How do we look after the planet? How do we make sure

642
00:32:07,533 --> 00:32:09,170
we're not destroying the environment?

643
00:32:09,171 --> 00:32:11,490
How do we reduce inequality?

644
00:32:11,491 --> 00:32:15,084
How do we create opportunity for more people

645
00:32:15,085 --> 00:32:18,600
to live decent lives and fulfilling lives?

646
00:32:19,130 --> 00:32:21,158
On the one hand, you can just sort of stick

647
00:32:21,159 --> 00:32:22,992
your head in the sand and say, look, it's not

648
00:32:22,993 --> 00:32:27,856
my responsibility, but I think that's not, again, not living

649
00:32:27,857 --> 00:32:31,168
up to what the world is offering you and the

650
00:32:31,169 --> 00:32:33,920
privilege you have to be part of the world, and

651
00:32:34,930 --> 00:32:37,070
you should rise to these challenges.

652
00:32:37,810 --> 00:32:40,842
When you work in physics, a very healthy attitude

653
00:32:40,843 --> 00:32:42,676
often is to say, look, I'm going to try

654
00:32:42,677 --> 00:32:49,118
something which sounds appealing, exciting, it may be risky,

655
00:32:49,119 --> 00:32:50,984
and I'll have a backup plan.

656
00:32:50,985 --> 00:32:53,016
If this doesn't work, if it's proven wrong.

657
00:32:53,017 --> 00:32:54,638
Well, there's so many other wonderful

658
00:32:54,639 --> 00:32:55,612
things to do in life.

659
00:32:55,613 --> 00:32:59,234
You don't have to follow the conventional path.

660
00:32:59,235 --> 00:33:02,748
And if you end up compromising to such an

661
00:33:02,749 --> 00:33:07,698
extent, that enables you to follow some conventional path.

662
00:33:07,699 --> 00:33:09,920
I feel you're really missing out

663
00:33:09,921 --> 00:33:12,950

on the possibilities which life offers.

664
00:33:12,951 --> 00:33:14,342
Have you always had a backup

665
00:33:14,343 --> 00:33:16,390
plan in mind throughout your career?

666
00:33:16,391 --> 00:33:18,288
I always did have a backup plan.

667
00:33:18,289 --> 00:33:22,228
I think in my own case, my parents both went to

668
00:33:22,229 --> 00:33:27,188
jail for their political beliefs, and then they came out of

669
00:33:27,189 --> 00:33:31,790
jail and a few decades later were elected to parliament.

670
00:33:33,350 --> 00:33:35,032
They had a complete turnaround where

671
00:33:35,033 --> 00:33:37,976
their beliefs actually led them into

672
00:33:37,977 --> 00:33:41,110
positions of responsibility in government.

673
00:33:41,111 --> 00:33:43,160
And so that was very inspiring for me.

674
00:33:43,161 --> 00:33:45,464
So I took from them that

675
00:33:45,465 --> 00:33:49,486
one really shouldn't compromise your beliefs.

676
00:33:49,487 --> 00:33:51,260
And, yes, I had a backup plan.

677
00:33:51,261 --> 00:33:53,180
I think even from when I was a graduate student,

678
00:33:53,181 --> 00:33:56,642
I was a bit worried about aspects of theoretical physics

679
00:33:56,643 --> 00:34:01,632
that I doubted whether these models were actually real.

680
00:34:01,633 --> 00:34:04,670
It was kind of a game people were playing,

681
00:34:04,671 --> 00:34:08,623
interesting game, but it somehow didn't really ring true.

682
00:34:08,624 --> 00:34:11,476
Grand unified theories or string theories never

683
00:34:11,477 --> 00:34:14,692
really felt to me like they were

684
00:34:14,693 --> 00:34:17,370
a genuine insight into reality.

685
00:34:17,371 --> 00:34:20,489
That's just a feeling, not necessarily

686
00:34:20,490 --> 00:34:22,868
one that you should trust.

687
00:34:22,869 --> 00:34:25,608
But as a result of that, I basically said to

688
00:34:25,609 --> 00:34:28,893

myself, look, if I don't make it in theoretical physics,

689
00:34:28,894 --> 00:34:32,312
if I'm not able to make a good contribution, my

690
00:34:32,313 --> 00:34:36,434
dream was I would go and be a wildlife warden

691
00:34:36,435 --> 00:34:39,947
in a game park in East Africa, because I thought

692
00:34:39,948 --> 00:34:42,219
there's sort of nothing more fun than sort of looking

693
00:34:42,220 --> 00:34:47,777
after lions and antelopes and rhinos in the wild.

694
00:34:47,778 --> 00:34:49,563
So, yeah, I always had that as a

695
00:34:49,564 --> 00:34:52,000
sort of at least a mental backup plan.

696
00:34:52,001 --> 00:34:54,214
If nobody wants me in, know I'll

697
00:34:54,215 --> 00:34:56,469
go and do something much more exciting.

698
00:34:56,470 --> 00:34:58,288
So, strange thing about me is that when

699
00:34:58,289 --> 00:35:01,728
I was a postdoc in California, I used

700
00:35:01,729 --> 00:35:04,148
to have a recurring sort of nightmare, which.

701
00:35:04,149 --> 00:35:07,252
And the nightmare was that I actually got a faculty position

702
00:35:07,253 --> 00:35:11,418
back in my original department in London, that I'd be walking

703
00:35:11,419 --> 00:35:15,470
down the corridor and I'd see these names on the doors,

704
00:35:15,471 --> 00:35:17,608
and I came to this door and my name was on

705
00:35:17,609 --> 00:35:21,400
it, and I woke up in a cold sweat. Oh, no.

706
00:35:21,401 --> 00:35:23,090
I'm a faculty member.

707
00:35:26,010 --> 00:35:28,492
The academic career is not

708
00:35:28,493 --> 00:35:32,250
the pinnacle of human experience.

709
00:35:32,251 --> 00:35:33,874
I love my colleagues.

710
00:35:33,875 --> 00:35:35,218
I like being an academic.

711
00:35:35,219 --> 00:35:38,338
I think university is a wonderful place for many reasons,

712
00:35:38,339 --> 00:35:41,372
but you should use them to enjoy it and have

713
00:35:41,373 --> 00:35:44,780

fun and not see that as a goal in itself.

714
00:35:45,390 --> 00:35:48,352
As you've said, a lot of these things you're bringing up

715
00:35:48,353 --> 00:35:51,248
are topics that I think students struggle a lot with.

716
00:35:51,249 --> 00:35:53,156
And you devote a lot of your time to

717
00:35:53,157 --> 00:35:56,548
mentoring and giving advice to students, including yesterday, you

718
00:35:56,549 --> 00:35:59,482
met with a large group of Psi and graduate

719
00:35:59,483 --> 00:36:02,132
students here, and a few of them sent in

720
00:36:02,133 --> 00:36:04,436
some questions for you that I'd like to share.

721
00:36:04,437 --> 00:36:07,390
So let's start with one from Saba.

722
00:36:08,290 --> 00:36:10,852
I'm Saba, and I'm a PSi student.

723
00:36:10,853 --> 00:36:12,404
And before coming to PSi, I

724
00:36:12,405 --> 00:36:13,882
was working mostly in cosmology.

725
00:36:13,883 --> 00:36:16,652
And then after entering PSi, I got

726
00:36:16,653 --> 00:36:19,468
introduced to this whole new ways of

727
00:36:19,469 --> 00:36:21,266
doing quantum gravity and quantum foundations.

728
00:36:21,267 --> 00:36:24,786
And I decided to somehow work in these directions

729
00:36:24,787 --> 00:36:28,594
while I'm in PI foundational aspects of quantum gravity.

730
00:36:28,595 --> 00:36:32,000
And now I'm at a stage in my life, like

731
00:36:32,001 --> 00:36:34,352
at the start of my PhD, that I'm really trying

732
00:36:34,353 --> 00:36:37,862
to figure out whether I should continue working on cosmology

733
00:36:37,863 --> 00:36:42,868
like I was doing before or continue doing this kind

734
00:36:42,869 --> 00:36:46,436
of quantum gravity and foundational aspects of quantum gravity from

735
00:36:46,437 --> 00:36:48,196
quantum information point of view.

736
00:36:48,197 --> 00:36:50,276
And the thing is, at this point,

737
00:36:50,277 --> 00:36:52,964
I feel that I found my question.

738
00:36:52,965 --> 00:36:54,776

And I think the question for me

739
00:36:54,777 --> 00:36:57,352
at the moment is to somehow figure

740
00:36:57,353 --> 00:36:59,790
out quantum gravity problem of quantum gravity.

741
00:36:59,791 --> 00:37:03,016
And I don't know what is the most

742
00:37:03,017 --> 00:37:06,490
promising avenue to somehow approach the question.

743
00:37:06,491 --> 00:37:07,778
The thing is cosmology.

744
00:37:07,779 --> 00:37:10,796
It looks like that at very early point,

745
00:37:10,797 --> 00:37:14,300
everything becomes classical, and we don't really know

746
00:37:14,301 --> 00:37:19,046
if by studying cosmology, how can I directly

747
00:37:19,047 --> 00:37:22,118
address the interest in quantum gravity?

748
00:37:22,119 --> 00:37:24,656
And, yeah, I just want to know

749
00:37:24,657 --> 00:37:26,432
your opinion about what do you think

750
00:37:26,433 --> 00:37:30,438
about cosmology in context of quantum gravity?

751
00:37:30,439 --> 00:37:31,328
What are the avenues that

752
00:37:31,329 --> 00:37:32,938
one can pursue inside cosmology?

753
00:37:32,939 --> 00:37:34,532
And what are the most promising ways

754
00:37:34,533 --> 00:37:37,710
to somehow do some phenological quantum gravity?

755
00:37:38,370 --> 00:37:40,884
Okay, thank you for the wonderful question.

756
00:37:40,885 --> 00:37:42,984
I think you are asking the right question.

757
00:37:42,985 --> 00:37:48,232
You're recognizing that we're gaining wonderful insights from

758
00:37:48,233 --> 00:37:51,016
observation in cosmology, and you want to apply

759
00:37:51,017 --> 00:37:53,752
it to learn something about quantum gravity, which

760
00:37:53,753 --> 00:37:58,402
is the big missing component in fundamental physics.

761
00:37:58,403 --> 00:38:00,444
The part of the standard model, if you

762
00:38:00,445 --> 00:38:03,938
like, that we understand least, is quantum gravity.

763
00:38:03,939 --> 00:38:06,140

So you're asking the right question.

764
00:38:06,141 --> 00:38:08,840
The problem is we don't know the answer yet.

765
00:38:09,370 --> 00:38:12,480
And I would say the following, that the sure

766
00:38:12,481 --> 00:38:16,870
bet over the next 1020 years is that observations

767
00:38:16,871 --> 00:38:18,774
are going to continue to bear fruit.

768
00:38:18,775 --> 00:38:21,146
We're going to get more and more precise measurements

769
00:38:21,147 --> 00:38:23,870
of the fluctuations coming out of the Big Bang.

770
00:38:24,450 --> 00:38:26,852
With that precision, we have much

771
00:38:26,853 --> 00:38:28,794
greater power to test theory.

772
00:38:28,795 --> 00:38:32,788
So I think that's a very sensible avenue for

773
00:38:32,789 --> 00:38:37,086
anyone to take, is to get into data analysis,

774
00:38:37,087 --> 00:38:41,432
interaction with observations, modeling the observations and so on.

775
00:38:41,433 --> 00:38:43,304
I think, and I hope many

776
00:38:43,305 --> 00:38:45,930
people will go into that direction.

777
00:38:45,931 --> 00:38:48,604
Now, I sense from your question that you

778
00:38:48,605 --> 00:38:52,604
are more attracted to the more fundamental questions.

779
00:38:52,605 --> 00:38:53,516
That's a great thing.

780
00:38:53,517 --> 00:38:57,020
But keep in mind that people have not

781
00:38:57,021 --> 00:39:00,640
solved this problem for more than 50 years,

782
00:39:00,641 --> 00:39:03,632
probably 75 years, people have been trying to

783
00:39:03,633 --> 00:39:07,390
solve these problems and failing repeatedly.

784
00:39:07,391 --> 00:39:10,000
So the chances of you're actually making

785
00:39:10,001 --> 00:39:12,850
success are very, very small at best.

786
00:39:12,851 --> 00:39:16,404
So what you can do, I think, is pick problems

787
00:39:16,405 --> 00:39:21,252
which are instructive, where you are dealing with gravity and

788
00:39:21,253 --> 00:39:25,752

sort of refining your understanding of Einstein's theory and of

789
00:39:25,753 --> 00:39:28,408
quantum mechanics, if you like, think about it.

790
00:39:28,409 --> 00:39:30,728
As a musician, we have all these wonderful works by

791
00:39:30,729 --> 00:39:35,672
classical composers, and it's great practice, as well as very

792
00:39:35,673 --> 00:39:39,948
rewarding just to sort of review those and give them

793
00:39:39,949 --> 00:39:43,884
your own spin and find better ways of explaining them

794
00:39:43,885 --> 00:39:45,138
and so on and so forth.

795
00:39:45,139 --> 00:39:48,262
And I think that kind of work is never wasted.

796
00:39:48,263 --> 00:39:52,670
So, provided you don't expect to really answer

797
00:39:52,671 --> 00:39:54,928
these very, very difficult questions, then I think

798
00:39:54,929 --> 00:39:57,958
you will find the work very rewarding.

799
00:39:57,959 --> 00:40:00,928
The chances that a solution to this

800
00:40:00,929 --> 00:40:04,202
puzzle will come, I'm very optimistic.

801
00:40:04,203 --> 00:40:05,732
The next ten or 20 years, there will

802
00:40:05,733 --> 00:40:08,692
be at least much better resolutions of these

803
00:40:08,693 --> 00:40:11,490
puzzles, but the chances are small.

804
00:40:11,491 --> 00:40:15,990
And exactly who finds it is a random question.

805
00:40:15,991 --> 00:40:17,496
It could be anyone, and

806
00:40:17,497 --> 00:40:19,950
probably it'll be somebody unexpected.

807
00:40:19,951 --> 00:40:24,264
So it might be a PhD student somewhere in a

808
00:40:24,265 --> 00:40:28,444
very minor institution who comes up with the key idea.

809
00:40:28,445 --> 00:40:29,730
That's one of the exciting

810
00:40:29,731 --> 00:40:32,172
things about fundamental research.

811
00:40:32,173 --> 00:40:33,160
Could be anyone.

812
00:40:33,690 --> 00:40:35,772
But if you're in a position where you are

813
00:40:35,773 --> 00:40:40,048

studying these questions carefully and rigorously, and you are

814
00:40:40,049 --> 00:40:44,102
very critically aware of the different approaches and frameworks,

815
00:40:44,103 --> 00:40:47,270
then you'll be in a good position to respond

816
00:40:47,271 --> 00:40:50,510
to any such breakthrough which happens.

817
00:40:50,511 --> 00:40:52,634
And if a breakthrough does happen, whether it's

818
00:40:52,635 --> 00:40:55,178
by you or by anyone else, obviously that's

819
00:40:55,179 --> 00:40:59,210
going to blossom into many, many other areas.

820
00:40:59,211 --> 00:41:02,548
The second we understand quantum gravity and

821
00:41:02,549 --> 00:41:04,888
how it relates to the universe, there

822
00:41:04,889 --> 00:41:07,838
will be a huge variety of outcomes

823
00:41:07,839 --> 00:41:12,070
and questions and predictions and interpretations.

824
00:41:12,071 --> 00:41:14,568
And that's something which you could

825
00:41:14,569 --> 00:41:16,876
easily spend a lifetime working on.

826
00:41:16,877 --> 00:41:20,146
Yeah, I would encourage you to go in that direction.

827
00:41:20,147 --> 00:41:22,306
Study it very carefully, very seriously.

828
00:41:22,307 --> 00:41:24,492
Don't put all your bets on one

829
00:41:24,493 --> 00:41:28,748
horse, because whatever horse you bet on

830
00:41:28,749 --> 00:41:31,926
is unlikely to be the correct approach.

831
00:41:31,927 --> 00:41:34,032
And as you said, these breakthroughs can

832
00:41:34,033 --> 00:41:36,288
come at any time and from anyone.

833
00:41:36,289 --> 00:41:38,224
And I know one thing you were very

834
00:41:38,225 --> 00:41:40,368
known for during your time as director at

835
00:41:40,369 --> 00:41:43,898
perimeter, was fostering an environment in this academic

836
00:41:43,899 --> 00:41:47,652
institution where those breakthroughs could take place from

837
00:41:47,653 --> 00:41:50,980
anyone, not necessarily just from senior faculty members.

838
00:41:50,981 --> 00:41:52,676

What do you think are the most

839
00:41:52,677 --> 00:41:56,376
essential ingredients that an academic institution needs

840
00:41:56,377 --> 00:41:58,558
in order to foster those breakthroughs?

841
00:41:58,559 --> 00:42:02,888
I think it's a recognition that the most likely people

842
00:42:02,889 --> 00:42:06,710
to come up with original ideas are the youngest.

843
00:42:06,711 --> 00:42:08,636
So I see the community of young people

844
00:42:08,637 --> 00:42:11,370
as the most important in the institute.

845
00:42:11,371 --> 00:42:13,836
Don't get big headed, those young people watching

846
00:42:13,837 --> 00:42:16,668
this, but I do see that, and I

847
00:42:16,669 --> 00:42:19,030
think, furthermore, they need to be very diverse.

848
00:42:19,031 --> 00:42:22,342
I think diversity is very often a source

849
00:42:22,343 --> 00:42:28,460
of strength and enthusiasm, and difference is very.

850
00:42:29,390 --> 00:42:32,452
It encourages new ways of thinking.

851
00:42:32,453 --> 00:42:33,626
It's a commonplace.

852
00:42:33,627 --> 00:42:36,932
But very often in physics, the best new

853
00:42:36,933 --> 00:42:40,852
ideas come about when two different strands of

854
00:42:40,853 --> 00:42:45,432
thought collide and suddenly realize that the other

855
00:42:45,433 --> 00:42:48,520
one has some insight they can benefit from.

856
00:42:48,521 --> 00:42:50,648
The Higgs mechanism in the Higgs boson is

857
00:42:50,649 --> 00:42:54,062
a classic example where Peter Higgs was aware

858
00:42:54,063 --> 00:42:58,108
of ideas happening in superconductivity, which were, by

859
00:42:58,109 --> 00:43:01,260
and large, ignored by particle physicists, mainly because

860
00:43:01,261 --> 00:43:04,514
particle physicists were fairly arrogant and they couldn't

861
00:43:04,515 --> 00:43:09,344
possibly believe that somebody studying materials could actually

862
00:43:09,345 --> 00:43:11,142
give them a real insight.

863
00:43:11,143 --> 00:43:15,328

But Higgs grabbed that insight and interpret it in

864
00:43:15,329 --> 00:43:19,142
terms of and incorporate it into particle physics.

865
00:43:19,143 --> 00:43:22,300
And that was extremely profound and important.

866
00:43:23,470 --> 00:43:26,122
You know, initially, it was resisted.

867
00:43:26,123 --> 00:43:27,588
People didn't believe what he was

868
00:43:27,589 --> 00:43:29,764
doing at all for several years.

869
00:43:29,765 --> 00:43:32,792
So, yeah, I think diversity of different

870
00:43:32,793 --> 00:43:34,872
types of people from different countries, from

871
00:43:34,873 --> 00:43:38,504
different cultures, especially gender diversity, is really

872
00:43:38,505 --> 00:43:41,780
important among that young physics community.

873
00:43:42,550 --> 00:43:46,200
Another very important thing is that the people who

874
00:43:46,201 --> 00:43:50,270
often are most original are very often od.

875
00:43:50,271 --> 00:43:53,484
In certain respects, they are unusual people,

876
00:43:53,485 --> 00:43:55,452
and they're not necessarily very good at

877
00:43:55,453 --> 00:43:59,710
coping with the everyday rigors of life.

878
00:43:59,711 --> 00:44:03,310
And so it's very important that any community

879
00:44:03,311 --> 00:44:08,560
which fosters talent be specially supportive of people

880
00:44:08,561 --> 00:44:12,138
who are unusual in whatever respect.

881
00:44:12,139 --> 00:44:14,130
So I think that's essential.

882
00:44:14,131 --> 00:44:19,578
And again, by supporting unusual people, different people, that's

883
00:44:19,579 --> 00:44:22,926
probably the best way of ensuring the field isn't

884
00:44:22,927 --> 00:44:28,232
a monoculture, all pursuing the same direction, which, as

885
00:44:28,233 --> 00:44:33,678
I've already expressed, the most popular directions haven't panned

886
00:44:33,679 --> 00:44:36,472
out in the last 40 years.

887
00:44:36,473 --> 00:44:39,228
And that's reason why we should make sure

888
00:44:39,229 --> 00:44:42,070

we pursue a real diversity of directions.

889
00:44:42,650 --> 00:44:44,252
Now, I want to ask you more about

890
00:44:44,253 --> 00:44:46,268
these unusual people and how you find them.

891
00:44:46,269 --> 00:44:48,172
But first, maybe let's just go to one

892
00:44:48,173 --> 00:44:49,904
more question sent in from a student.

893
00:44:49,905 --> 00:44:51,536
This one was sent in from

894
00:44:51,537 --> 00:44:54,288
Batsalia, who's a Psi student.

895
00:44:54,289 --> 00:44:57,072
And he wrote in asking, do you think that

896
00:44:57,073 --> 00:45:00,628
as theoretical physicists, it is our moral responsibility to

897
00:45:00,629 --> 00:45:03,412
pursue research that explains the real world?

898
00:45:03,413 --> 00:45:05,076
Or is it okay to just

899
00:45:05,077 --> 00:45:07,630
enjoy playing with mathematical structures?

900
00:45:08,850 --> 00:45:10,836
Yeah, that's a difficult question.

901
00:45:10,837 --> 00:45:11,892
I think, above all, that

902
00:45:11,893 --> 00:45:14,600
theoretical physics is very hard.

903
00:45:14,601 --> 00:45:16,126
It's a kind of torture.

904
00:45:16,127 --> 00:45:19,672
We do these very difficult, complicated calculations, and they

905
00:45:19,673 --> 00:45:23,048
take days or weeks or months, and sometimes you

906
00:45:23,049 --> 00:45:27,474
just end up with a paradox and confusion.

907
00:45:27,475 --> 00:45:29,810
So it's not an easy life choice,

908
00:45:29,811 --> 00:45:31,880
but somehow we do enjoy it.

909
00:45:32,970 --> 00:45:35,916
And so I think, in order to make sense of

910
00:45:35,917 --> 00:45:38,364
why we enjoy it, it's quite good to have at

911
00:45:38,365 --> 00:45:42,454
least some idea why, some idea of our motivation.

912
00:45:42,455 --> 00:45:44,486
I've met a lot of theoretical physicists

913
00:45:44,487 --> 00:45:46,662

who like nothing more than making diagrams.

914
00:45:46,663 --> 00:45:50,054
And they say they like writing papers because it's

915
00:45:50,055 --> 00:45:52,448
a chance to make a diagram that they can

916
00:45:52,449 --> 00:45:54,468
put in the paper, but the part of it

917
00:45:54,469 --> 00:45:56,394
they actually enjoy is making the diagram.

918
00:45:56,395 --> 00:45:58,954
So people do it for all kinds of reasons.

919
00:45:58,955 --> 00:46:03,710
I don't think there's much of a moral responsibility.

920
00:46:03,711 --> 00:46:06,600
I see it more as a responsibility to yourself.

921
00:46:06,601 --> 00:46:07,928
Don't delude yourself.

922
00:46:07,929 --> 00:46:10,980
I guess that would be my overriding message.

923
00:46:11,670 --> 00:46:15,128
If you like playing with mathematical frameworks, and if

924
00:46:15,129 --> 00:46:17,308
you're good at it, then by all means do

925
00:46:17,309 --> 00:46:20,060
it, because the work you do will be good.

926
00:46:20,061 --> 00:46:23,666
And other people may well draw some interesting physical

927
00:46:23,667 --> 00:46:26,994
conclusions, even if your work is just mathematical.

928
00:46:26,995 --> 00:46:30,416
So I would never denigrate anyone for doing something

929
00:46:30,417 --> 00:46:33,856
they enjoy, especially when they're doing it well, even

930
00:46:33,857 --> 00:46:36,102
if it doesn't directly relate to physics.

931
00:46:36,103 --> 00:46:39,900
It's more like playing a game, a mathematical game.

932
00:46:40,590 --> 00:46:43,988
That's fine to do, but as I say, in

933
00:46:43,989 --> 00:46:46,228
a certain sense, feel sorry for them, because I

934
00:46:46,229 --> 00:46:49,012
think the real magic of physics is that these

935
00:46:49,013 --> 00:46:53,934
mathematical considerations end up connecting with reality.

936
00:46:53,935 --> 00:46:56,180
That's the deep mystery of the field.

937
00:46:56,710 --> 00:46:59,460
Somebody said this to me a few days ago.

938
00:47:00,630 --> 00:47:03,368

Mathematicians make their frameworks and do

939
00:47:03,369 --> 00:47:06,872
their calculations, but physicists somehow have

940
00:47:06,873 --> 00:47:08,520
a direct line to God.

941
00:47:09,610 --> 00:47:10,892
Now, I don't believe in God.

942
00:47:10,893 --> 00:47:15,100
I'm not religious, at least not in any organized sense,

943
00:47:15,101 --> 00:47:17,554
but I think there's a kind of element of truth

944
00:47:17,555 --> 00:47:22,438
in that, that somehow physicists have uncovered a fundamental feature

945
00:47:22,439 --> 00:47:28,390
of existence, which is this strange ability of our minds

946
00:47:28,391 --> 00:47:32,530
to really make sense of what's around us.

947
00:47:32,531 --> 00:47:35,972
It's a very deep puzzle, and I think, if you like,

948
00:47:35,973 --> 00:47:39,988
the best way we can appreciate that puzzle and further it

949
00:47:39,989 --> 00:47:45,208
and pay it homage, almost, is to practice that, to make

950
00:47:45,209 --> 00:47:49,288
sure what we do does, or to try to relate the

951
00:47:49,289 --> 00:47:52,150
mathematics we do to the real world.

952
00:47:52,151 --> 00:47:54,344
In many ways, you're speaking to this idea

953
00:47:54,345 --> 00:47:57,996
that physics needs many different people, including people

954
00:47:57,997 --> 00:48:00,876
who like to make diagrams, or maybe people

955
00:48:00,877 --> 00:48:03,298
who might be considered unusual.

956
00:48:03,299 --> 00:48:05,084
Yes, absolutely.

957
00:48:05,085 --> 00:48:06,636
Another way to say it is people

958
00:48:06,637 --> 00:48:10,098
that don't necessarily succeed in the traditional

959
00:48:10,099 --> 00:48:13,142
academic hierarchy that we've constructed.

960
00:48:13,143 --> 00:48:14,608
So I guess, as a director, it must have

961
00:48:14,609 --> 00:48:18,256
been very challenging to find the right people, because

962
00:48:18,257 --> 00:48:20,752
you probably couldn't just look at the applications they

963
00:48:20,753 --> 00:48:24,052

submitted, which are maybe trying to show you other

964
00:48:24,053 --> 00:48:26,308
metrics than the ones you would want.

965
00:48:26,309 --> 00:48:28,836
So how did you go about finding the right people?

966
00:48:28,837 --> 00:48:31,898
Yes, so I think that this was something I'm

967
00:48:31,899 --> 00:48:35,432
particularly proud of as director, is that when I

968
00:48:35,433 --> 00:48:38,152
came to perimeter, the faculty was very small.

969
00:48:38,153 --> 00:48:41,368
It wasn't really structured at all, and it

970
00:48:41,369 --> 00:48:44,310
wasn't clear how it should be structured.

971
00:48:44,311 --> 00:48:47,826
The government and supporters had made big investments

972
00:48:47,827 --> 00:48:50,508
in perimeter, and it was very important.

973
00:48:50,509 --> 00:48:54,402
Those paid off in the sense that the institute

974
00:48:54,403 --> 00:48:58,352
actually did good work, and it became recognized as

975
00:48:58,353 --> 00:49:01,856
a place where excellent theoretical physics was done.

976
00:49:01,857 --> 00:49:04,006
So it was quite a challenge.

977
00:49:04,007 --> 00:49:06,528
And I think I took the point of

978
00:49:06,529 --> 00:49:11,088
view that we needed very rare people here.

979
00:49:11,089 --> 00:49:13,748
There was nothing stopping us from recruiting from all over

980
00:49:13,749 --> 00:49:16,628
the world, and we needed to look as widely as

981
00:49:16,629 --> 00:49:19,364
possible and sort of keep our eyes and ears open

982
00:49:19,365 --> 00:49:23,998
for unusual people who'd done something unexpected.

983
00:49:23,999 --> 00:49:26,302
So it wasn't a matter of reading

984
00:49:26,303 --> 00:49:30,710
applications or it was really being proactive.

985
00:49:30,711 --> 00:49:34,926
I also learned that the senior physicists who were advising

986
00:49:34,927 --> 00:49:39,532
us weren't always, or even often the best source of

987
00:49:39,533 --> 00:49:43,708
ideas as to who to hire, because usually they had

988
00:49:43,709 --> 00:49:47,610

their own field and their own visibility.

989
00:49:47,611 --> 00:49:51,310
Region that was visible to them was very limited.

990
00:49:51,311 --> 00:49:54,608
And secondly, if they saw somebody really good they

991
00:49:54,609 --> 00:49:56,118
thought was really good, they would try and hire

992
00:49:56,119 --> 00:49:59,264
them themselves and not recommend them to us.

993
00:49:59,265 --> 00:50:00,836
So that was interesting.

994
00:50:00,837 --> 00:50:03,396
So I think the short answer was just by

995
00:50:03,397 --> 00:50:06,308
really keeping eyes and ears open and looking for

996
00:50:06,309 --> 00:50:11,754
very unusual people who maybe had unconventional career paths.

997
00:50:11,755 --> 00:50:15,352
And then imagine what would happen is when you

998
00:50:15,353 --> 00:50:18,974
hired them, if you gave them much more freedom

999
00:50:18,975 --> 00:50:22,110
than are usually given to young faculty.

1000
00:50:22,111 --> 00:50:24,168
So, one of the rules we introduced is that

1001
00:50:24,169 --> 00:50:26,780
as a young faculty member, you should not spend

1002
00:50:26,781 --> 00:50:31,602
more than 20% of your time on administrative duties.

1003
00:50:31,603 --> 00:50:33,682
So that includes teaching,

1004
00:50:33,683 --> 00:50:36,650
mentoring, applying for grants.

1005
00:50:36,651 --> 00:50:40,190
And that's extremely unusual, because most universities,

1006
00:50:40,191 --> 00:50:42,502
when a young faculty member arrives, they're

1007
00:50:42,503 --> 00:50:47,062
immediately loaded with teaching and grant applications,

1008
00:50:47,063 --> 00:50:48,992
and they're very often judged on their

1009
00:50:48,993 --> 00:50:50,406
success in winning grants.

1010
00:50:50,407 --> 00:50:51,972
And I think that's very

1011
00:50:51,973 --> 00:50:55,780
antithetical to pursuing original research.

1012
00:50:55,781 --> 00:50:58,930
So I would always tell the young faculty,

1013
00:50:58,931 --> 00:51:02,770

go after some problem that really fascinates you.

1014
00:51:02,771 --> 00:51:05,400
If you don't publish anything for

1015
00:51:05,401 --> 00:51:08,232
two, three years, no problem.

1016
00:51:08,233 --> 00:51:11,352
You will explain to us that I went after this very

1017
00:51:11,353 --> 00:51:14,950
difficult problem, and we will all respect you for that.

1018
00:51:14,951 --> 00:51:17,676
We're investing in you because we think you

1019
00:51:17,677 --> 00:51:21,186
have the capability of doing something unusual.

1020
00:51:21,187 --> 00:51:24,178
And so please go after something unusual.

1021
00:51:24,179 --> 00:51:27,084
And of course, we will advise you and try to

1022
00:51:27,085 --> 00:51:31,168
make sure you do enough to keep your career going.

1023
00:51:31,169 --> 00:51:32,896
But it should be a much more

1024
00:51:32,897 --> 00:51:36,384
sort of supportive framework than is usually

1025
00:51:36,385 --> 00:51:39,366
provided to young faculty in universities.

1026
00:51:39,367 --> 00:51:40,356
So I see it.

1027
00:51:40,357 --> 00:51:43,156
The job of an institution is more to

1028
00:51:43,157 --> 00:51:47,578
challenge people to really be adventurous and ambitious,

1029
00:51:47,579 --> 00:51:50,852
rather than to judge them all the time,

1030
00:51:50,853 --> 00:51:57,646
and particularly on criteria like publications, citations, conference

1031
00:51:57,647 --> 00:51:59,528
talks given, and all that.

1032
00:51:59,529 --> 00:52:04,046
These are really the sort of symptoms of physics.

1033
00:52:04,047 --> 00:52:06,748
They're not the essence of what we're trying to do.

1034
00:52:06,749 --> 00:52:09,260
So in many ways I try to set an example

1035
00:52:09,261 --> 00:52:12,988
where perimeter used very different metrics to judge people.

1036
00:52:12,989 --> 00:52:16,620
I think metrics like how creative are they,

1037
00:52:16,621 --> 00:52:20,528
how stimulating are they to have around, do

1038
00:52:20,529 --> 00:52:23,712

they have original ideas, do they question things?

1039
00:52:23,713 --> 00:52:25,790
Are they asking good questions?

1040
00:52:25,791 --> 00:52:30,032
Those characteristics of people are actually

1041
00:52:30,033 --> 00:52:31,892
much more important than the more

1042
00:52:31,893 --> 00:52:34,452
conventional measures of success.

1043
00:52:34,453 --> 00:52:36,404
It seems like it really involves looking at

1044
00:52:36,405 --> 00:52:39,012
the institute as a whole rather than just

1045
00:52:39,013 --> 00:52:42,356
evaluating whether each individual person is.

1046
00:52:42,357 --> 00:52:46,158
Yes, one of the biggest diseases of the academic

1047
00:52:46,159 --> 00:52:49,128
model, particularly in North America, is the idea that

1048
00:52:49,129 --> 00:52:51,288
every researcher has a grant, and they use the

1049
00:52:51,289 --> 00:52:54,760
grant to support their postdocs and their students.

1050
00:52:54,761 --> 00:52:57,010
So what you're doing is deliberately

1051
00:52:57,011 --> 00:53:00,428
putting individual researchers in competition with

1052
00:53:00,429 --> 00:53:04,146
one another and deliberately creating hierarchies.

1053
00:53:04,147 --> 00:53:05,362
And I see this everywhere.

1054
00:53:05,363 --> 00:53:07,648
It's also becoming increasingly common in

1055
00:53:07,649 --> 00:53:10,016
Europe and elsewhere, I'm sure.

1056
00:53:10,017 --> 00:53:14,070
And I think this model of the single investigator

1057
00:53:14,071 --> 00:53:16,912
at the top of a pyramid is actually very

1058
00:53:16,913 --> 00:53:23,498
destructive of creativity, originality, questioning, because the more junior

1059
00:53:23,499 --> 00:53:26,132
people don't want to question the senior person who

1060
00:53:26,133 --> 00:53:30,692
holds the cash, and I think that's the wrong

1061
00:53:30,693 --> 00:53:32,532
way to do things.

1062
00:53:32,533 --> 00:53:36,318
I much prefer a much flatter structure.

1063
00:53:36,319 --> 00:53:39,678

And actually conceptually, I think a much better picture

1064
00:53:39,679 --> 00:53:44,184
is an inverted pyramid, where the senior people, if

1065
00:53:44,185 --> 00:53:46,696
you like, are at the bottom and their job

1066
00:53:46,697 --> 00:53:49,564
is precisely to support the younger people.

1067
00:53:49,565 --> 00:53:53,004
And the flowers on the tree, they can be the

1068
00:53:53,005 --> 00:53:55,132
root, but the flowers on the tree are the young

1069
00:53:55,133 --> 00:53:58,364
people and that's really where the emphasis should be.

1070
00:53:58,365 --> 00:54:00,524
It seems like a lot of the things you

1071
00:54:00,525 --> 00:54:03,792
would ideally look for, like being creative, asking good

1072
00:54:03,793 --> 00:54:06,592
questions, are things that are maybe more difficult to

1073
00:54:06,593 --> 00:54:09,152
measure or difficult to predict ahead of time.

1074
00:54:09,153 --> 00:54:11,472
So I guess another essential ingredient is

1075
00:54:11,473 --> 00:54:13,610
maybe being okay with taking risks.

1076
00:54:13,611 --> 00:54:15,636
And I'm just wondering if that's true.

1077
00:54:15,637 --> 00:54:19,172
Is it important to kind of embrace the fact that some

1078
00:54:19,173 --> 00:54:22,996
of those choices you make might not work out very much?

1079
00:54:22,997 --> 00:54:26,008
So, as I say, when I talk to students

1080
00:54:26,009 --> 00:54:29,272
today, I'm very often struck by, they say, well,

1081
00:54:29,273 --> 00:54:32,232
I'd like to do something more exciting and more

1082
00:54:32,233 --> 00:54:35,086
interesting, but it would be risky.

1083
00:54:35,087 --> 00:54:38,268
I find that very disappointing that people, I understand

1084
00:54:38,269 --> 00:54:42,188
it, they need to ultimately make a living.

1085
00:54:42,189 --> 00:54:45,282
As a generality, young people today are much less secure

1086
00:54:45,283 --> 00:54:48,972
than they were in my day as a student, we

1087
00:54:48,973 --> 00:54:51,638
felt that sort of if, for whatever reason, things don't

1088
00:54:51,639 --> 00:54:54,432

work out, there are plenty of alternative options.

1089
00:54:54,433 --> 00:54:56,830
And we weren't nervous about

1090
00:54:56,831 --> 00:54:58,272
livelihoods in the same way.

1091
00:54:58,273 --> 00:55:00,752
There are very good economic reasons for that.

1092
00:55:00,753 --> 00:55:03,732
The ability to find jobs is certainly more

1093
00:55:03,733 --> 00:55:06,372
difficult today than it was several decades ago.

1094
00:55:06,373 --> 00:55:08,596
And even my generation, it was much

1095
00:55:08,597 --> 00:55:11,466
harder than it was in previous generations.

1096
00:55:11,467 --> 00:55:15,342
Previously, universities were really, or at least advanced

1097
00:55:15,343 --> 00:55:18,936
research was the privilege of a very small

1098
00:55:18,937 --> 00:55:21,208
number of people, and as a result they

1099
00:55:21,209 --> 00:55:23,752
had much greater job security and didn't really

1100
00:55:23,753 --> 00:55:27,106
worry about getting academic positions.

1101
00:55:27,107 --> 00:55:28,876
So my professors never really

1102
00:55:28,877 --> 00:55:30,588
worried about this at all.

1103
00:55:30,589 --> 00:55:32,386
I didn't have to get grants.

1104
00:55:32,387 --> 00:55:34,012
Money was more or less just

1105
00:55:34,013 --> 00:55:38,902
provided in the field has changed.

1106
00:55:38,903 --> 00:55:42,320
Part of that has been letting larger numbers in

1107
00:55:42,321 --> 00:55:44,416
to the field, which is a good thing.

1108
00:55:44,417 --> 00:55:47,248
Widening access means greater pool of

1109
00:55:47,249 --> 00:55:49,910
talent and things should move faster.

1110
00:55:49,911 --> 00:55:52,932
But what has come along with that is much

1111
00:55:52,933 --> 00:55:57,604
more standardization and prescription, telling young people, you've got

1112
00:55:57,605 --> 00:55:59,764
to do ABC to get a job.

1113
00:55:59,765 --> 00:56:01,668

And I think that's been damaging, and I

1114
00:56:01,669 --> 00:56:05,272
see this all across higher education actually, is

1115
00:56:05,273 --> 00:56:08,046
that the quality of degrees now being awarded

1116
00:56:08,047 --> 00:56:10,264
I don't think is what it should be.

1117
00:56:10,265 --> 00:56:14,568
Even if you look at undergrad degrees, the

1118
00:56:14,569 --> 00:56:18,146
curriculum has become very standardized and rather dull.

1119
00:56:18,147 --> 00:56:20,098
Initiative is not rewarded.

1120
00:56:20,099 --> 00:56:22,738
So this is not in isolation, it's

1121
00:56:22,739 --> 00:56:26,972
everywhere, this sort of massification and then

1122
00:56:26,973 --> 00:56:31,230
standardization and loss of creativity.

1123
00:56:31,231 --> 00:56:33,686
So theoretical physics is very fortunate

1124
00:56:33,687 --> 00:56:36,160
because it's such a cheap field.

1125
00:56:36,161 --> 00:56:37,488
We just need a blackboard and

1126
00:56:37,489 --> 00:56:39,630
chalk and occasionally a computer.

1127
00:56:39,631 --> 00:56:41,156
It's really a very cheap field.

1128
00:56:41,157 --> 00:56:44,570
So if anybody is going to recreate

1129
00:56:44,571 --> 00:56:49,892
the organization of science more optimally, it

1130
00:56:49,893 --> 00:56:52,050
has to be theoretical physics.

1131
00:56:52,051 --> 00:56:55,406
We have one of the most effective of all sciences,

1132
00:56:55,407 --> 00:56:58,254
if not the most effective in terms of predictions.

1133
00:56:58,255 --> 00:57:01,438
Theoretical physics can't be matched.

1134
00:57:01,439 --> 00:57:04,296
We have the cheapest, we have the

1135
00:57:04,297 --> 00:57:06,936
easiest, the most universal easiest to access.

1136
00:57:06,937 --> 00:57:09,388
You don't need a lab, you can come to

1137
00:57:09,389 --> 00:57:12,172
a summer school and learn some ideas, and they

1138
00:57:12,173 --> 00:57:15,690

may enable you to write a very interesting paper.

1139
00:57:15,691 --> 00:57:18,528
So theoretical physics should be setting the

1140
00:57:18,529 --> 00:57:21,014
example for the rest of science.

1141
00:57:21,015 --> 00:57:23,232
So it's very, very important that we

1142
00:57:23,233 --> 00:57:27,174
strategize our field carefully and wisely.

1143
00:57:27,175 --> 00:57:29,536
I don't think that's happening in general.

1144
00:57:29,537 --> 00:57:31,440
You've also said in many ways that

1145
00:57:31,441 --> 00:57:33,862
diversity is a very important ingredient.

1146
00:57:33,863 --> 00:57:35,764
And it just reminds me of something that I

1147
00:57:35,765 --> 00:57:37,956
noted down that you said yesterday when you were

1148
00:57:37,957 --> 00:57:40,036
meeting with students that I really like.

1149
00:57:40,037 --> 00:57:43,178
You said theoretical physics is special because it's

1150
00:57:43,179 --> 00:57:46,936
cross cultural and everyone has the same questions. Yes.

1151
00:57:46,937 --> 00:57:48,408
And so I just wanted to ask you,

1152
00:57:48,409 --> 00:57:50,968
because you have, throughout your career, traveled all

1153
00:57:50,969 --> 00:57:53,656
around the world, met with researchers at every

1154
00:57:53,657 --> 00:57:56,444
level and from everywhere, what do you think

1155
00:57:56,445 --> 00:57:59,800
are those questions that everyone is asking?

1156
00:58:00,330 --> 00:58:01,746
Well, I was very struck.

1157
00:58:01,747 --> 00:58:04,220
For example, I'll tell you one little story.

1158
00:58:04,221 --> 00:58:07,122
So I was in Senegal, I was teaching

1159
00:58:07,123 --> 00:58:10,880
electromagnetism, relativity, and there was a student who

1160
00:58:10,881 --> 00:58:14,170
had done maths at university, so not physics.

1161
00:58:14,830 --> 00:58:17,424
It was kind of a lively student.

1162
00:58:17,425 --> 00:58:20,576
So I asked the whole class when I started

1163
00:58:20,577 --> 00:58:22,484

the course, what would you like to be?

1164
00:58:22,485 --> 00:58:25,710
And his answer was, a billionaire.

1165
00:58:27,010 --> 00:58:30,714
Which actually, you can say it's kind of crass, but compared

1166
00:58:30,715 --> 00:58:33,524
to the other students who largely said, I want to be

1167
00:58:33,525 --> 00:58:37,198
a professor, I found it more exciting to have somebody who's

1168
00:58:37,199 --> 00:58:41,576
at least not just saying, I want to repeat exactly what

1169
00:58:41,577 --> 00:58:43,672
the people who taught me and so on.

1170
00:58:43,673 --> 00:58:45,358
Anyway, so he wanted to be a billionaire.

1171
00:58:45,359 --> 00:58:48,248
So we started chatting, and then

1172
00:58:48,249 --> 00:58:50,354
he was very puzzled by physics.

1173
00:58:50,355 --> 00:58:52,338
What is all this stuff you keep referring

1174
00:58:52,339 --> 00:58:54,588
to reality and light and all that, and

1175
00:58:54,589 --> 00:58:57,450
you're writing down some equations and so on.

1176
00:58:57,451 --> 00:58:59,708
So then we had at some point,

1177
00:58:59,709 --> 00:59:03,072
an interaction about the problem sheets, and

1178
00:59:03,073 --> 00:59:05,334
at some point it involved instabilities.

1179
00:59:05,335 --> 00:59:06,688
And at some point, I was trying

1180
00:59:06,689 --> 00:59:08,544
to explain what this instability was.

1181
00:59:08,545 --> 00:59:10,448
And at some point he said to me,

1182
00:59:10,449 --> 00:59:13,230
oh, you mean physics is just logic?

1183
00:59:15,010 --> 00:59:17,796
And I said, yes, that's exactly what it is.

1184
00:59:17,797 --> 00:59:19,978
It's logic applied to nature.

1185
00:59:19,979 --> 00:59:22,772
He said, now I get it right.

1186
00:59:22,773 --> 00:59:24,104
And then he got very interested.

1187
00:59:24,105 --> 00:59:26,888
And then in subsequent days, and this is the

1188
00:59:26,889 --> 00:59:30,136

wonderful thing about meeting someone from a completely different

1189
00:59:30,137 --> 00:59:35,224
culture and background, academically as well as culturally and

1190
00:59:35,225 --> 00:59:39,612
linguistically, everything, he started to, you know, you can

1191
00:59:39,613 --> 00:59:43,330
apply logic to the real world, and then naturally,

1192
00:59:43,331 --> 00:59:43,932
what do you do?

1193
00:59:43,933 --> 00:59:45,138
You point to the stars.

1194
00:59:45,139 --> 00:59:46,892
And in Senegal, where we were,

1195
00:59:46,893 --> 00:59:48,114
it was in a nature reserve.

1196
00:59:48,115 --> 00:59:49,676
It was actually a wonderful place.

1197
00:59:49,677 --> 00:59:51,808
And there's this huge open sky with the

1198
00:59:51,809 --> 00:59:54,830
stars, and you immediately say, what are those?

1199
00:59:54,831 --> 00:59:56,998
What's the logical basis of stars?

1200
00:59:56,999 --> 00:59:59,792
And then that was an excuse to have a conversation about

1201
00:59:59,793 --> 01:00:03,810
how stars form and how they work and nuclear physics.

1202
01:00:03,811 --> 01:00:08,292
So, yes, people very naturally ask the same questions.

1203
01:00:08,293 --> 01:00:10,132
It's because we all live in the same

1204
01:00:10,133 --> 01:00:13,352
universe and we're all sort of puzzled and

1205
01:00:13,353 --> 01:00:15,950
amazed by the same natural phenomena.

1206
01:00:15,951 --> 01:00:20,398
And so that is the cultural unifier, the realization

1207
01:00:20,399 --> 01:00:23,512
that the phenomena which are just around us all

1208
01:00:23,513 --> 01:00:27,368
the time and which are miraculous in various ways,

1209
01:00:27,369 --> 01:00:29,852
that we can share this, we all do share

1210
01:00:29,853 --> 01:00:33,004
it, and we can discuss with each other and

1211
01:00:33,005 --> 01:00:35,436
share our understanding of how that works.

1212
01:00:35,437 --> 01:00:37,346
And that somehow gives you a grip

1213
01:00:37,347 --> 01:00:40,170

on the world, which you share.

1214
01:00:40,171 --> 01:00:41,872
And I do think also it makes

1215
01:00:41,873 --> 01:00:44,454
you feel more responsible, more empowered.

1216
01:00:44,455 --> 01:00:47,638
If you understand the world, you're certainly much more empowered

1217
01:00:47,639 --> 01:00:50,230
than if you're just kind of at its mercy.

1218
01:00:50,231 --> 01:00:53,476
And so I think this understanding between different

1219
01:00:53,477 --> 01:00:57,044
cultures, different people's fundamental understanding of the world

1220
01:00:57,045 --> 01:01:00,074
is very empowering, is very unifying.

1221
01:01:00,075 --> 01:01:05,614
It makes us all feel we're part of the same enterprise.

1222
01:01:05,615 --> 01:01:09,448
And so that's really the most exciting thing of all.

1223
01:01:09,449 --> 01:01:10,952
Well, Neil, thank you so

1224
01:01:10,953 --> 01:01:12,974
much for this amazing conversation.

1225
01:01:12,975 --> 01:01:15,788
It's been so much fun to talk to you. Thank you.

1226
01:01:15,789 --> 01:01:16,920
Thank you very much.

1227
01:01:19,770 --> 01:01:22,562
Thanks so much for stepping inside the perimeter.

1228
01:01:22,563 --> 01:01:25,650
Be sure to subscribe so you don't miss a conversation.

1229
01:01:25,651 --> 01:01:29,138
We've interviewed a lot of really brilliant scientists whose

1230
01:01:29,139 --> 01:01:32,092
research spans from the quantum to the cosmos, and

1231
01:01:32,093 --> 01:01:34,252
we can't wait for you to hear more.

1232
01:01:34,253 --> 01:01:36,364
And if you like what you hear, please give us

1233
01:01:36,365 --> 01:01:39,650
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1234
01:01:39,651 --> 01:01:42,020
Break science is for everyone, so

1235
01:01:42,021 --> 01:01:43,440
help us spread the word.

1236
01:01:46,610 --> 01:01:46,860
Close.